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PROFESSOR H. G. SEELEY, F.R.S., F.G.S., ETC.

INVERTEBRATA (INTRODUCTION).

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MOLLUSCA.

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TUNICATA.

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MOLLUSCOIDA (BRACHIOPODA AND BRYOZOA).

AGNES CRANE.

INSECTA (INTRODUCTION).

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HYMENOPTERA.

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CASSELL'S NATURAL HISTORY.



COMMON PIKE.

57

CLASS PISCES.—FISHES.

CHAPTER I.

GENERAL INTRODUCTION.—THE ANATOMY AND OTHER CHARACTERISTICS OF FISHES.

Immense Variety of Forms—Characteristics of the Class—Industrial Importance to Man—Fecundity—Colour—Mental Endowments—Their General Structure—The Lowest Type of Fish—Structural Features in Sharks and Rays—The Skull—Peculiarities in the Lepidosiren—Skull of Codfish—The Sense Capsules—Teeth and Jaws—The Branchial Arches—The Muscles of Fishes—The Skin and Mucous System—To what Causes the Colour of Fishes is Due—The Scales of Fishes—Agassiz's Classification based on Scales—The Nervous System—The Spinal Cord—The Brain—Organs of Smell, Sight, and Hearing—The Electric Organs—The Teeth of Fishes—The Alimentary Canal—The Liver—The Air-bladder—The Blood—The Heart—The Gills—Fins and their Functions—Classification of the Fishes.

FISHES are the only primary division of the Vertebrata which live in water, and have no representatives passing their lives upon land or in the air. This condition of existence is probably the cause of the close correspondence in bodily form in the majority of fishes, which progress through the water chiefly by movements of the tail, and use the fins as organs with which to steer a path. Clear as is the idea which rises in the mind at the mention of a fish, the multitudes of forms which fishes exhibit are greater, perhaps, than those to be found in any of the preceding great

groups of animals which have already been described. The slender form of the Lauprey or Eel contrasts with the expanded body of the Turbot or Plaice; the short deep form of the Sun-fish is unlike the broad, flattened, and long-tailed Skate; the Sea Horses, when attached by their prehensile tails, at first sight present none of the familiar characteristics of fishes; the Flying-fish, which have the fins so expanded as to serve some of the purposes of wings, present a remarkable contrast to the spheroidal spiny body of the Globe-fish; while the Hammer-headed Shark exhibits a form of body in some respects more singular still. When we turn to details of proportion and structure, and contrast the shapes of the head or of the tail, the variety among fishes is altogether exuberant. In the covering of the body there is not so much scope for variation, for although some are contained in a box of bony plates, or mailed with armour far heavier in proportion than that of the knights of old, and some fishes have, on the other hand, scales so delicate that they are detected with difficulty, yet by far the larger number of living fishes are clothed with soft scales, which impart to them much of their beauty, and differ in little more than size and details of ornament in the multitudinous genera. But beyond the claims upon our attention which the external forms of fishes certainly make, an interest of a far higher kind is always aroused by their wonderful habits. Here we find the herbivorous and carnivorous types of the land reproduced. Many fishes—like the Sword-fish, for instance—seem specially moulded into shape for purposes of slaughter; many fishes, like most of those with transversely-expanded bodies, pass their lives more or less quietly on the bottom of the sea, and simulate the sand they rest upon; other groups, like Eels, dive into the sand as though it were their natural home; others, again, like the Gurnards, crawl with their appendages at the sides of the head, almost like some of the Crabs, when they are not freely swimming. Some fishes, like the Sturgeon, find their home indifferently in fresh or salt water; several, like the Salmon, require to descend annually from the river to the sea. Multitudes of fishes travel in fellowship year by year over a large portion of the ocean, a few fresh-water fishes journey over land, and one or two are sometimes found roosting like birds in the branches of trees.

The industries which fishes have contributed to develop have given this group of animals an importance scarcely second to mammals and birds. No small proportion of the food of mankind is obtained by the fleets of fishing-boats around the coasts, and by the humbler nets, and snares, and lines with which fishes are captured in rivers and lakes. The use of fish for manure is of ancient date; the capture of fishes for the manufacture of medicinal and other oils, gelatine, and isinglass is carried on on a large scale; the skins of Sharks have always been valued for the decoration of some kinds of military weapons no less than by the cabinet-maker for their rasping properties. Much of the artificial jewellery, which resembles pearls so closely as almost to equal the natural production of the sea-shell *Avicula margaritifera*, owes its beauty to a preparation from the scales of the Bleak and other fishes.

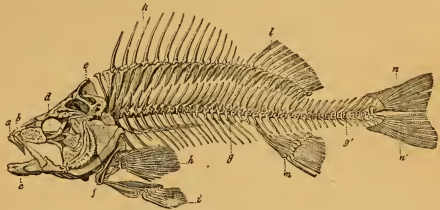
The fecundity of fishes far surpasses that of any other group of vertebrated animals. The eggs laid by a single fish sometimes may be counted by millions. They are almost always small—as may be seen in the ordinary hard roe of the fishes which are eaten—and are frequently minute. They pass through no metamorphosis, as do the young in their development among the higher group named Amphibia; but occasionally fishes are viviparous, and then the young are retained within the body of the parent until they have reached a relatively large size. Fishes furnish us with the smallest examples of the Vertebrates which are known, and also with some of the biggest forms, though they never make any approach to the giant length of the larger Whales. By far the greater number of fishes are of relatively small size.

As with mammals and birds, the great majority of fishes are characterised by comparatively dull colours, which probably serve to conceal them from enemies, and have been developed as a means of enabling them to mimic the aspects of the regions of sea and river which they frequent. But all are not so simply decorated. The brilliant colours of the gold and silver and violet Carp are well known. Many fishes are striped and spotted, or burnished with colours which almost rival those of gaudy birds, and it would be difficult to name a tint which could not be matched among some representatives of the fish class. Too little, however, is known of the habits and ways of life of these highly-coloured fishes to enable us to judge how far they are an advantage to the species which are thus characterised.

In the matter of mental endowment fishes are probably but little, if at all, inferior to the majority of the so-called higher animals. The angler knows well their caution, discrimination, cunning, and boldness, and how often his own powers and patience are exerted in vain in entrapping a fish who has grown wise as well as old in observation of the phenomena of the river in which he lives. Fishes would appear to be capable of affection, since Sharks, at least, frequently swim in pairs. Some genera are capable of being trained, and a few are known to be gifted with vocal organs which, to judge from the analogy of higher animals, may fairly be regarded as a means for the inter-communication or expression of emotions and experiences. Removed as fishes are from the conditions of daily observation by living in water, fewer observations have necessarily been made upon their intellectual characteristics than is the case with animals which can be more easily studied.

In their general structure or anatomy fishes are usually well distinguished from other animals. Their most distinctive structures are, perhaps, the possession of gills and an air-bladder. But they are no less well defined by the peculiar forms assumed by the limbs which we call fins, and by the simplicity of the plan upon which the immense muscles, which form the larger part of the fish's body, are arranged. The variety in structure, however, presented by fishes is so great that the lowest type—represented by the Lancelet—seems almost to pass beyond the limits of the fish group, standing alone in its simplicity and in many details of structure in which a parallel can be traced with yet lower animals. Other fishes also diverge so far from the typical forms as to possess lungs, as may be seen in the *Ceratodus* of the Australian rivers, and in the Mud-fish, called *Lepidosiren*. It may be useful briefly to mention the chief characteristics of the several groups of organs of this class of animals.

In the lowest type of fish, of which the Lancelet (*Amphioxus lanceolatus*) is the only representative, the cranium is merely a forward continuation of the rod which represents the vertebral column. This rod is named the *notochord*, or *chorda dorsalis*, and consists of a fibro-gelatinous substance, which is not covered with cartilage or with bony matter. This gives a very imperfect conception of the skull as usually seen in fishes; yet a jointed cartilaginous arch extends downward round the region of the mouth, and is a foreshadowing of the arch which is more perfectly developed around the mouth in the Lampreys. In simplicity of skull-structure the Sharks and Rays are the next step in the upward series, but there are many points in connection with these animals which lead to the belief that they are among the highest types of fish. The *notochord* is now converted into firm granular cartilage, sheathed in bone, and divided into segments by bone deposited in its substance; but it extends forward along the base of the skull, and develops two oblong convex surfaces, which are termed the occipital condyles, by which the back of the skull unites with the first vertebra. This mode of union of the skull with the vertebral column is characteristic of amphibians and mammals, and since the other Vertebrates have the skull united to the vertebral column by a single occipital condyle, it has sometimes been thought that we may discern herein a special indication of affinity between the skulls of Sharks and those of the Amphibia, which, it will be remembered, possess, when they commence their existence, many of the structures of fishes. There is no distinction of bones, however, in the brain-case, but the bony matter is deposited in countless little cells. Its base is flat; the sides are contracted; it is usually flattened above, with one or more open spaces, or *fontanelles*, which are covered only with

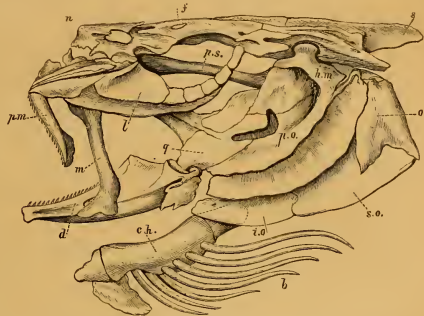


SKELETON OF THE COMMON PERCH.

a, Pre-maxillary Bone; b, Maxillary Bone; c, Under Jaw; d, Palatine Arch; e, Cranium; f, Operculum; g, g', Vertebral Column; h, Pectoral Fin; i, Ventral Fin; j, k, Dorsal Fins; l, Anal Fin; m, Caudal Fin.

membrane. Indeed, this bony structure cannot truly be called a brain-case, since it is merely a covering on the outside of the cartilage which contains the brain. The arches appended to this cranium are a single strong pedicle on each side, which is articulated to an angular posterior process, and has attached to it the arch which is called the mandible, or lower jaw, and the arch which is considered to correspond to the tongue-bone in reptiles and birds, and is hence called the hyoid. The maxillary arch, or upper jaw, is closely joined to its fellow in front by a ligament, and is attached by ligaments to the anterior part of the cranial region, and is prolonged backward so as to articulate with the lower jaw. Each lateral half of the jaw consists of a single cartilage, or cartilage sheathed in bone, and thus far is comparable only with the jaws in mammals. According to Sir R. Owen, there are also cartilages which represent the palatine and pterygoid bones in the Monk-fish and in a Brazilian Torpedo. Four or five cartilaginous rays diverge from the hinder margin of the pedicle which supports the jaws, and have stretched upon them a membrane which corresponds to the operculum in bony fishes. The hyoid arch in the Shark family usually consists of two long and strong lateral pieces, which are united to a middle symmetrical piece below, which is flattened, termed the basi-hyoid. The two lateral portions, which rise from this like horns, and are hence termed the cerato-hyoids, give off short cartilaginous processes from their hinder margins, which correspond to the bones which are termed branchiostegal rays in bony fishes, and support the outer membrane of the sac which contains the gills. The five branchial arches which extend backward behind the hyoid arch are suspended from the sides of the front vertebrae of the trunk, just as in the Lamprey. In Sharks three strong cartilages are prolonged forward from the head, which coalesce in the middle line and form the remarkable snout. In these fishes the shoulder girdle is suspended a little behind the head. The ear is contained in a cartilaginous capsule in the walls of the cranium, the eye is united by a cartilaginous pedicle with the orbit, and the nasal sacs are arched over by nasal processes from the skull. Another modification of skull is seen in the Lepidosiren, where the separate bones of the skull are distinctly formed. The fibrous sheath of the notochord is ossified at the anterior end, and the ex-occipital bones rise from it, and expand and converge so as to meet above the foramen magnum. A large cartilaginous capsule surrounds the internal ear, but there is a long basi-cranial bone with cartilaginous plates at the sides. Other bones of the upper part of the skull also have representatives. Each branch of the lower jaw consists now of two pieces—the hinder portion, termed the articular, and the anterior, termed the dentary, though the two dentary pieces have become united together in the middle line in front. There are some slight representatives of the opercular arch. There is a single cerato-hyoid bone on each side, but no basi-hyoid. In one of his lectures Sir R. Owen remarked of this fish:—"I believe it to manifest, upon the whole, the highest grade which is attained in the class of fishes, or in the direct progress to perfection in what may be termed the vertebrate high road. The true or typical osseous fishes deviate from this road into bypaths of their own, and superadd endless complexities, of which we shall seek in vain for homologous parts in reptiles, birds, or mammals. The Lepidosiren's skeleton presents the closest resemblance to that of the lowest class of reptiles, though it differs therefrom both by a little less and a little more development." The skull in osseous fishes is altogether different. It may be convenient, as the modifications which it presents are so multitudinous, to bear in mind as one type the skull of the Codfish (*Gadus morhua*), which is one of the largest and commonest British species. The head is larger in proportion to the trunk in fishes than in any other class of animals. It is more or less conical. The base of the cone joins the trunk without any intervening neck; the jaws are usually at the apex of the cone, which is flattened above, and has the sides more or less converging below. The eyes are large, and the orbits communicate with each other. There are two lateral fissures behind the head, which are called the gill-apertures, and are opened and closed by special mechanism. Besides receiving the food, the mouth takes in streams of water for respiration, which, after bathing the gills, escape by the gill-apertures or openings behind the operculum. The head also contains the heart and the whole of the breathing organs, and the anterior limbs are often in very close union with the skull. There are more bones in the head of a fish than in the head of any other animal. Most of these bones unite with each other by overlapping, like scales. The brain is contained in a cranial cavity, so that the bones fit closely upon it. The upper surface of the head is often marked by longitudinal crests, but

it does not often happen that the temporal muscles, which work the lower jaw, extend to the upper surface of the cranium, though this sometimes occurs, as in the Conger Eel and in the Lepidosiren. The bones of the skull, as in man, are divided into those of the brain-case and those of the face, but in fishes the facial bones are far more developed than in man. The hindmost bone at the back of the skull, by which it joins the first vertebra, varies a good deal in form. In most fishes, as in the Carp, it is a deep conical cup, but in the Halibut it is almost flat, and in *Fistularia* it presents a convex surface, which is exactly comparable with the condition seen in a Lizard or Crocodile. This bone, which is termed the basi-occipital, in many fishes has a process prolonged downward from its under side, and in the Carp this broad triangular plate supports the large upper grinding-tooth in the throat, reminding one of the way in which processes from the neck vertebrae are prolonged into the œsophagus in certain Snakes and Lizards. There are two bones rising from the basi-occipital which arch over the beginning of the brain; they are termed the ex-occipitals. They are usually perforated for the pneumo-gastric nerve, and sometimes for other nerves also. The bone above these is called the supra-occipital. In the Cod it is prolonged backward in a median spine; in the bony Pike (*Lepidosteus*) it is double, being divided by a suture in the middle line. Sometimes the crest of the bone is exceedingly lofty, as in the Light Horseman fish (*Ephippus*), and sometimes absent, as in the sucking fish *Remora*. At the sides of the ex-occipitals are two bones, termed by Owen par-occipitals, and by Huxley opisthotic bones. The distinction of these bones in the lower Vertebrates is a characteristic feature of the skull, but in the Polypterid they unite with the ex-occipital bones, as in Batrachian reptiles, and in the Chelonia they unite with the mastoid bones, as in the Chelonia. The organ of hearing in fishes is usually large. In front of this girdle of cranial bones, which Sir R. Owen long ago compared to one of the trunk vertebrae, is a similar series of bones with a median basal bone, now called the para-sphenoid, and closely resembling the para-sphenoid of Amphibians, which reaches along the greater part of the base of the skull, exactly as in that group. In the flat fishes its anterior end is twisted upon one side of the skull. It is always smooth below, and in the genus *Polypterid* the bones which rise from its sides are blended with it. There is some difference of opinion with regard to the names to be given to these bones. The hindmost bone is termed by Owen ali-sphenoid, and by Huxley prootic. These bones are arched over by the parietals. In the Salmon family the two parietals soon unite together. In the Silurid fishes they also unite with the supra-occipital bone, but in many osseous fishes the supra-occipital bone extends between them. They are always flattened above. In some fishes they are perforated by nerves which supply the vertical fins of the back. In front of the parietal bones is the principal frontal, which roofs over the orbits in all animals. It carries a median crest in the Cod and some fishes, and varies in shape with the form of the skull. In the Tunny each frontal has a crest of its own, and in some Silurid fishes and the Loach there is a fontanelle between the frontal and parietal bones which corresponds in position with the so-called *foramen parietale*, which is characteristic of many fossil and living reptiles. In the flat fishes the frontal is single. Behind it at the sides are the post-frontal bones, which assist in arching over the auditory cavities, and help to furnish a support for

SKULL OF CODFISH (*Gadus morhua*). [After Owen.]

n, Lacrymal; *n*, Nasal; *f*, Frontal; *s*, Supra-occipital; *p.m.*, Pre-maxillary; *m*, Maxillary; *i.o.*, Inter-occipital; *s.o.*, Sub-occipital; *q*, Quadrate; *c.h.*, Ceratohyal; *b*, Branchiostegal Ray; *p.o.*, Para-sphenoid; *d*, Dentary.

the tympanic pedicle. At their anterior corners are the pre-frontal bones, which defend and support the olfactory prolongation of the brain, and form the front border of the orbit. On the base of the skull, wedged into the para-sphenoid, is the vomer; its upper surface supports the nasal bones. In the genus *Lepidosteus* it is divided longitudinally into two. In many fishes the vomer carries teeth. The pre-frontals and nasals are both sometimes blended with the vomer. The nasal bone is broad in the Salmon, but varies in shape in other fishes. In the genus *Lophius* and in the *Diodonts* it is unossified, being represented by membrane. The nasal bone completely divides the nasal cavity into two lateral pits. Between the orbits there is often a partition, which is sometimes cartilaginous and sometimes membranous. The turbinal bones of man, on which the olfactory nerve is spread out, are represented in the fish, and placed at the sides of the nasal bones. The nasal bone sometimes supports teeth, and teeth are frequently found on the palatine bones.

The sense capsules are well fitted into cavities of the skull in bony fishes. The auditory organ becomes blended with the cartilaginous base of the skull in *Lepidosiren*, and there are distinct otic bones, which protect the labyrinth of the ear in many bony fishes. These auditory capsules are often closed externally, but have a wide opening into the cranial cavity. The eye in cartilaginous fishes is contained in a cartilaginous capsule, but in most osseous fishes the capsule is bony. Bony plates are developed in some fishes in the sclerotic or hard outermost covering of the eye. In most fishes the bony orbits for the eyes communicate with each other, but the Shads, *Hydrocyon*, *Synbranchus*, *Cyprinus*, and many other genera have a bony septum between the orbits, and in the Ganoid fishes of the genera *Lepidosteus* and *Polypterus* the orbits are divided, as among the *Batrachia*, by a double septum, which forms the walls of the olfactory prolongation of the brain.

The bones which form the jaws may conveniently be considered together. They are somewhat differently arranged in fishes to their condition in other animals, but the bones are still easily identified by the same names; thus pterygoid, palatine, maxillary, and pre-maxillary still mark the order of succession of the bones of the palate from behind forward. The palatine bones unite in front with the maxillary, pre-frontal bone, and vomer, though in some fishes certain of the attachments are made by ligaments. The palatine usually forms the roof of the mouth as well as the floor of the orbit, and is always short and broad in the fishes with broad heads and small mouths, and long and slender in the fishes with wide mouths. The presence or absence of teeth on the palatine bone furnishes an excellent character for distinguishing many genera. The maxillary bone is usually small and toothless, and lies between the palatine bone behind and the pre-maxillary in front. In shape it is usually like the pre-maxillary, but more slender. In the Salmon tribe it unites with the hinder end of the pre-maxillary, which is short, and carries teeth along its margin. This condition also occurs in the Herring family, while in the *Plectognathi*, or Globe-fishes, the maxillary and pre-maxillary are blended into one bone. In the genus *Lepidosteus* these bones, although forming a single toothed border to the upper jaw, are subdivided into several bony pieces, but in the genus *Polypterus* the maxillary shows no signs of subdivision. This bone is very small in the Siluroid fishes, and both it and the pre-maxillary are entirely wanting in some of the Eels. The pre-maxillary bones are usually movably connected together at their anterior ends, but in the genus *Diodon* they are completely blended. The blended pre-maxillaries form the sword-like weapon in front of the snout carried by the Sword-fish (*Xiphias*) and by the Gar-pike. The pterygoid and transverse bones are not always present, though they occur in the majority of fishes. In the Salmon tribe and Eels they are blended with the palatine, and in some other fishes, like the genera *Lophius* and *Synodon*, they are entirely absent. Both these bones sometimes support teeth. The mandible, or lower jaw, is sometimes united in the median line in front by bony union, but sometimes the union is made by ligament. In front there is a bone which carries the teeth, called the dentary bone. This usually contains within it a cartilage, which is known as Meckel's cartilage, and the other bones placed behind the dentary are arranged around this cartilage. The lower jaw, however, joins the skull in osseous fishes in a way that is quite unparalleled among other animals. There is a distinct arch formed by a series of bones, which supports both the mandible and the gill-cover, and this arch is prolonged up the sides of the head, so as to unite with its side in the auditory region. The mandibular arch, however, is not altogether distinct from another arch placed behind it, which is termed the hyoid arch, and corresponds with the bones which in higher animals are connected with the tongue. The several portions of the hyoid have received

distinct names: first there is the basi-hyal in the middle, and from this a bone termed the glosso-hyal usually extends into the substance of the tongue. At the sides rise up the long horn-like bones termed cerato-hyal, above this is the epi-hyal, and yet higher still the stylo-hyal. All these tracts are not universally met with. In the Conger Eel, for instance, stylo-hyal is a ligament, and the basi-hyal is blended with the cerato-hyal. In other fishes, like the genus *Murenophis*, the glosso-hyal is wanting. From the hinder margin of the cerato-hyal and epi-hyal a number of slender, long, curved bones are prolonged backward and outward. These are termed the branchiostegal rays. They support the membrane which forms the external cover to the chamber which contains the gills. Their number is very variable, but most usually seven, as in the Cod. In the Herrings of the genus *Elops* there are more than thirty rays in each gill-cover. In the Carp they are flat and broad, and reduced to three in number. In the Angler they are enormously long. Behind the hyoid arch, and more or less connected with it, are the branchial arches. Originally there were six of these arches, one behind the other, with clefts between them, but only five are commonly developed. The first four support the gills, the fifth, margined with teeth, guards the entrance to the gullet. The lower ends of these arches are united to a chain of little bones prolonged backward from the basi-hyal element of the hyoid. This part, usually termed basi-branchial, most frequently consists of three bones. Each branchial arch rises from this outward and upward. It consists of three or four separate pieces of bone, though the fifth arch commonly consists of one bone only. Sometimes these arches become complicated in fishes which live long out of water, such as the Climbing Perch, by developing at their upper margins large bony folds, in the recesses of which water is contained, so that it may trickle from them over the gills. Occasionally the branchial arches remain cartilaginous, and all six pairs retain the cartilaginous condition in *Lepidosiren*, but the second and third arches do not support gills, though they are found on the last arch. The scapular arch of the fish is often attached to the side of the skull, or occasionally to the basi-occipital, though in the cartilaginous fishes it is usually removed farther back. It consists of several bones, which have received different names from the several anatomists who have described them. In Sir R. Owen's system the uppermost piece is the supra-scapula, which sometimes consists of two short columnar bones attached to the auditory region of the skull. The next piece is termed the scapula, and these two bones are always blended together in the Siluroid fishes. The lower bone Sir R. Owen terms the coracoid. They are sometimes blended together at their lower margins, but more frequently these bones are joined by ligament, though in the Siluroids they unite by a toothed suture. The bones which Owen names scapula and supra-scapula Huxley, with good reason, calls clavicle and supra-clavicle. The scapula and coracoid in all animals form the arch which gives attachment to the base of the limb. These bones support and defend the heart in all fishes, and give attachment to the diaphragm which separates the cardiac cavity from the abdominal cavity. They also furnish a margin against which the operculum shuts, enclosing the cavity which contains the gills.

The vertebrae in fishes present many curious modifications. Thus, in the Sturgeon the first five or six neural arches are blended together so as to form a sheath of cartilage which encloses the spinal cord and the front part of the notochord, the tapering end of which is prolonged into the base of the skull. The ribs are attached only to about the first twelve of the trunk vertebrae. They join the vertebrae by simple heads, and often consist of two or three jointed pieces. The same kind of union of the earlier dorsal vertebrae into a continuous cartilaginous sheath around the notochord is formed by the first ten vertebrae of the Chimæroids. In some of the Sharks the ribs become very numerous, extending in *Acanthias* to forty pairs. Among the Skates of the genus *Rhinobatis*, Sir R. Owen finds but a single arch over the bodies of two vertebrae, and in the Chimæra the slender rings which represent the bodies of the vertebrae in the cartilage covering the notochord are more numerous than the neural arches which extend over them. In the Blue Sharks the vertebrae are most perfectly ossified, having only four notches for the neural arch and transverse processes. In most bony fishes the vertebrae are conically cupped at both ends; often the body of the vertebra remains distinct from the neural arch. In most animals the front of a vertebra is easily recognised by the processes called zygapophyses, which yoke the bones together in front and behind, the articular surfaces in front always being directed upward or inward, but in the Perch the reverse condition is met with. The posterior zygapophysis here looks upward, and receives upon its surface the

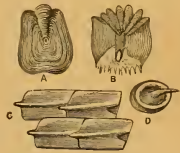
overlapping anterior process of the next succeeding vertebra. The transverse processes are short in the Salmon and Herring, but very long in the Cod family. As these transverse processes approach the tail they bend down and form a canal which arches over the blood-vessels in exactly the same way as the neural arch protects the spinal cord. The ribs of fishes sometimes articulate with the ends of the transverse processes, occasionally beneath them, and sometimes behind them, but the ribs are not united to a sternum, as is the case in the higher Vertebrata. A considerable number of fishes, such as Globe-fish, Sun-fish, and Pipe-fish have no traces of ribs. The most singular example of vertebrae becoming blended together is seen in the neck of the Pipe-fish (*Fistularia*), in which four neck vertebrae are united into a mass like the sacrum in birds. A true sacrum, however, occasionally exists, as in the Turbot, where two vertebrae are blended together, and in other fishes, like the genus *Loricaria*, a longer sacrum is developed. The number of vertebrae in osseous fishes is smaller than in the cartilaginous fishes. In the genus *Gymnotus*, however, there are 236, but in the Sun-fish Sir R. Owen enumerates only eight abdominal vertebrae, and eight in the tail. In the American bony Pike the vertebrae have the bodies convex in front and concave behind, but no fish is known in which the reverse condition of the cup in front and ball behind is met with. Often in fossil fishes the bodies of the vertebrae are unossified, while the neural arches are well developed. Then the notochord is said to be persistent, and occasionally it is sheathed in rings of bone.

The muscles of fishes are arranged on each side of the body in a series of successive flakes, which correspond in number with the vertebrae. Each of these flakes is attached by its inner border to the corresponding region of the skeleton and by its outer border to the skin. Each muscle or flake is contained in a sheath of connective tissue, which dissolves when the fish is boiled, so that the flakes then readily separate. The fibres of each muscle-flake run straight and nearly horizontally from one partition to the next, so that they extend longitudinally in the length of the fish. In the tail especially these muscles overlap each other, so as to present the same conical form at their ends as is seen in the tails of Crocodiles and Lizards. There are longitudinal divisions of the muscles in most osseous fishes which correspond more or less closely with those observed in the fish-like Batrachia and Ophidia. Towards the head these muscles become specially modified. Both the jaws in fishes are movable as a rule; and the large square muscle which draws the mandible backward stretches from the tympanic region to the maxillary bone, and by another branch to the coronoid process of the lower jaw. This muscle tends to open the fish's mouth. Other muscles widen the back of the mouth, and contract the branchial cavity. There is a series of muscles attached to the hyoid apparatus and the opercular bones by which the requisite muscular movements necessary to respiration are brought about. The branchial arches are similarly supplied with muscles. The muscles of the pectoral fin are arranged in two layers on each side; the fibres run in opposite directions, so as to cross each other. The inner pair retracts the fin, drawing it back so as to touch the side of the body. The outer pair extends the fin or moves it in the opposite direction. Then there are special muscles for depressing and raising the fin. Similar muscles control the ventral fins. Muscular fibres act upon the rays, and there are muscles to expand the rays and move the fins in the various directions which they are capable of taking. The median fins have three or four pairs of small muscles attached to each ray, and by these the rays are elevated and depressed. The caudal fin is moved by three series of muscles, but the variations in the muscular system of fishes are extremely numerous. The sucker of the mouth of the Lamprey is worked partly by a circular muscle, termed a sphincter, like that which closes the mouth or the eye in man, and partly by a series of muscles connected with the hyoid cartilage and with the lateral muscles of the body. The Trunk-fish, which is sheathed in bone, and is therefore incapable of lateral movement, has the longitudinal muscles of the body reduced to a thin layer. The muscles attain their greatest development among the Sharks. In fishes the substance of the muscle is usually colourless, owing to the small quantity of blood which it contains; but in some Sharks and the Sturgeon the muscles of the pectoral fins and the caudal extremity are deeply coloured, and nearly all the muscles of the Tunny are red, like those of mammals. The orange-red colour of the flesh in the Salmon and Charr is not due so much to the colour of the blood as to a peculiar oil which exists in the sheaths of the muscular fibres.

The skin is tightly stretched over the body in fishes, and enjoys but little sensibility, through being, for the most part, clothed with scales. In the Lamprey the skin consists of two layers, with

flattened fibres running at right angles to each other; the outer layer, or epidermis, is full of large star-shaped pigment cells, but devoid of scales. The Eel has a soft and thick epidermis. Below the pigment layer are the narrow oblong scales, which are formed of a finely reticulate cartilage. In the genus of Blennies named *Zoarces* there are circular depressions over the skin, due to minute round scales embedded in the dermis. Most osseous fishes possess flexible scales, marked with either concentric or radiating lines, or both combined. In these scales there is usually a nucleus, which may be irregular. The radiating lines diverge from the circumference of this nucleus. These lines are very numerous in the scales of the Loach (*Cobitis*). The parts of the margin of the scale between the radiating lines usually project in little convexities, and when the irregularities are limited to one end of the scale that end of the scale is usually implanted in the skin. In many fishes the free end of the scale is bordered with tooth-like processes. The surface of the body in most fishes is lubricated with a thin layer of mucus, but in the Eel and Tench the mucous layer is thick. This fluid is secreted by a canal which extends along the body, and has many ramifications among the bones of the head, where it exudes through pores upon the cranium, face, jaws, pre-operculum, and through tubes which perforate the scales along what is called the lateral line, usually distinguished on the sides of the fish by a lighter or darker colour. Rymer Jones remarks that after a fish has been dried in a napkin it soon becomes covered again with mucus, which issues from the pores. In the Tunny (*Thynnus thynnus*), there may be seen beneath the skin, running the entire length of the lateral line, a glandular organ, from which the little tubes are given off to the lateral line. The mucous system, however, is best developed in the Rays. In the genus *Acanthoclinus* there are several lateral canals which give off short tubes, which tunnel a way through the scales as they pass onward. Sir Rich Owen remarks that the silvery and golden lustre of fishes is mostly on the surface of the scales. The silvery pigment known in commerce under the name of argentine consists of very minute crystals of various earthy substances scraped from the scales, which often also occur upon some of the internal organs. The blue, red, green, and other bright colours of fishes are usually due to coloured oils, which occupy cavities in the skin, and are capable of changing their position, so as to alter the colour of the fish under the influence of excitement, or in harmony with the colour of the seabed upon which the fish is living. Many fishes change colour after death.

The scales of fishes consist of two layers. The lower layer resembles the fibro-cartilage of the human body, while the upper layer contains cartilage cells similar to those which are seen in the bluish cartilage covering a joint. The parts of a scale are defined in relation to the nucleus or focus from which growth originates. The longitudinal lines which run out from this nucleus sometimes form furrows and sometimes perfectly closed tubes. The broad plates which form the armour of the Pipe-fish are penetrated by canals, which all converge from the margins towards the middle of the scale. The concentric lines of scales are found to originate in the development of new cells, which become filled with horny matter, and ultimately arrange themselves in concentric lines. Scales show, when examined with the microscope, corpuscles, which are similar to those seen in bone. The fibrous layer of the scale may easily be found by scraping off the external cellular lines and corpuscles, when the fibres of the lower layer will be seen to cross each other at various angles. The growth of the spines upon scales appears to be similar to the growth of teeth, for each spine is contained in a distinct capsule or envelope. When the capsule is opened the spine can be easily removed from it, but as the germ develops it acquires roots, and comes to consist of several layers. Professor Agassiz, impressed with the differences of form in the scales, at one time believed that fishes might be classified by means of them, and he proposed to divide the scales into four types: as those which were bony, and formed of a thick osseous layer, covered with hard transparent enamel, as in the genera *Lepidosteus* and *Polypterus*, were termed Ganoids; those dermal spines or tubercles seen in the Thornback and many other cartilaginous fishes, which have a spine arising from a more or less circular bony base, were called Placoid scales; the scales which have the free margin more or less comb-shaped were termed Ctenoid; and those marked with a concentric structure were named Cycloid.



SCALES OF FISH.

A, Cycloid; B, Ctenoid; C, Ganoid;
D, Placoid.

To the two latter groups the great multitude of living fishes belong, but in the earlier ages of the earth's history Ganoid fishes were the prevailing types. Hence the older and less perfectly ossified division of fishes has been named by Dr. Günther, Palæichthyes.

The nervous system in fishes presents an unusual amount of variation. In the Skates there is a slight enlargement of the spinal column in the region where the large nerves are given off to the pectoral fins, and the same condition may be noticed in a less degree in the Sharks, but no corresponding enlargement of the spinal cord has been noticed in the Flying-fish or any other osseous fishes. In the Sturgeon there is a slight enlargement of the spinal cord at the beginning of the caudal region; in the Sun-fish the spinal cord is said to be reduced to a short conical appendage to the brain; and in the genera *Tetrodon* and *Diodon* the spinal cord is exceedingly short and small, but it has not the ganglionic structure seen in the Sun-fish. But in most fishes the spinal cord is as long as the neural canal. It is often marked by longitudinal fissures along the ventral and dorsal surfaces; and in the Sturgeon there is a less complete lateral groove dividing the spinal cord into dorsal and ventral columns. And in many fishes, such as the Cod and Herring, six cords may be distinguished: two of which are dorsal, and govern sensation; two ventral, and govern motion; and there are also two lateral regions. As the spinal cord approaches the brain it enlarges. According to Sir Rich. Owen, fishes are especially distinguished by having lobes which correspond to the great vagus nerve, or pneumogastric, as it is usually called, extending into the fourth ventricle of the brain, which is a cavity at the beginning of the medulla oblongata, or part where the brain becomes connected with the spinal cord.

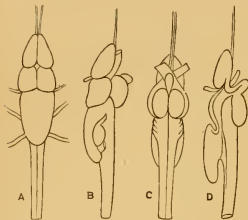


DIAGRAM OF BRAIN OF CODFISH.

A, Upper; B, Side; C, Under; D, Section.

The brain has its parts always arranged one behind the other in longitudinal succession, as among Amphibia and Reptiles. There is a hindmost part, which is single, called the cerebellum, which in most fishes is comparatively small, but becomes large and marked with transverse folds in the Sharks and Rays. Placed in front of this are two more or less rounded or ovate masses of brain, called the optic lobes. Farther still in front is the cerebrum, which usually consists of two masses, which may be larger or smaller than the optic lobes; but among the Sharks and Skates these masses of the brain are usually more or less blended together. In many fishes there are, besides, large olfactory lobes placed in front of the cerebrum, and from these the nerves of smell are prolonged. The nerves are

given off from the brain, precisely as in other animals, and the spinal cord prolonged down the vertebral column gives off nerves usually from between the vertebrae, though occasionally, as among some Sharks, they pass through perforations in the bony arches which cover the spinal cord.

In most osseous fishes the cerebellum is smooth and convex; it is frequently hemispherical, as in *Amblyopsis*, a genus of blind fish. In the Eel it is transversely elliptical; in *Lepidosteus* it is longitudinally elliptical; it is oblong in the genus *Diodon*; it is a depressed tongue-shaped body in the Cod; it is pyramidal in the Perch, and attains an immense development in the Sharks, where it extends 'over the optic lobes, which is also the case in the genus *Amblyopsis*; while in the Saw-fish it extends forward so far as to rest upon the cerebrum. It is largest in the most active fishes, is very small in the Lump-fish, is unsymmetrical in some of the flat fish, has a longitudinal groove in the genus *Diodon*, and is transversely divided in the genus *Lophius*. The fishes in which it shows the branching interior structure called the "arbor vite," due to the grey matter being folded over the white nervous matter, are Sharks and the Tunny. Another peculiarity of the Skate tribe, and found in most of the allied fishes, is the development of large convoluted lobes at the sides of the medulla oblongata, in the position where the fifth nerve is given off, a condition well seen in the Torpedo and in the *Chimæra monstrosa*. The optic lobes are usually the largest portion of the fish brain; they are spheroidal. Prolonged downward from this region is that remarkable part of the brain called the pituitary body, and upward the pineal gland is given off in front. There is a cavity in the optic lobes, which is one of the ventricles. It is quite exceptional for the optic lobes to be smaller

than the cerebral lobes of the brain, as they are in the genera *Polypterus* and *Lepidosiren*. In the Blind Fish (*Amblyopsis*) the optic lobes are exceedingly small. In several fishes, such as the Sturgeon, the optic lobes are almost completely united into one mass, but even where they are most widely separated, as in the Perch and the Herring, they are connected by a transverse band which passes in front of the third ventricle. The cerebral hemispheres often have a pinkish appearance, and the nervous matter is fissured and sometimes nodulated, but never approaches the convolute character seen in the higher mammals. These nervous masses are large, smooth, and elongated in many fishes, and in the Sharks become blended together; but in the bony fishes the cerebrum is proportionately small, especially in the Herring. It is also small in the Perch and Bream, but is relatively largest in the Ganoid fishes, which have hemispheres exceptionally large. The cerebral lobes are usually solid, but sometimes contain a lateral ventricle. The olfactory lobes are two distinct masses of grey nervous matter, which are never united by a transverse band, and may be in contact with each other in front of the cerebrum or widely separated. The true olfactory nerve consists of a group of distinct fibres, where it is given off from the olfactory lobe of the brain. The cerebral hemispheres of fishes correspond to that portion of the brain in mammals known as the *corpora striata*.

The relative size of the brain to the body may be gathered from the fact that in a Carp weighing 11,280 grains the brain weighed fourteen grains. As with higher animals, the brain acquires its full size before the fish has attained its full growth, and hence is relatively smaller in old fishes than in young ones. The great development of the medulla oblongata in fishes has a direct relation to the large size of the respiratory organs, or gills. The development of the cerebellum, so remarkably seen in the Sharks and Rays, is connected with active locomotion. Sir Rich. Owen observes that there is a distinct relation between the form of the brain and the habits of the fish, but all fishes of the same habit have not the same types of brain. "Thus the Shark and Pike are ferocious and predatory, the Angler and Skate are crafty, the Sword-fish and Stickleback love fighting, and the Barbel and Carp are timid, peaceful browsers. If the cerebral hemispheres of the Shark and Pike are compared, these parts of the brain differ more in shape, size, and structure than in any other fishes, though they are equally sanguinary, equally insatiable, both unsocial, and are tyrants, one of the sea and the other of the lake. The cerebrum of the Pike is smaller than the cerebellum; in the Shark it is larger than all the rest of the brain. In the Pike the two lobes are distinct, and united only by a narrow transverse band, but in the Shark they are blended into one large globular mass. In the Pike the cerebral lobes are narrow, but in the Carp it feeds upon they are broad, and in the fighting Stickleback the cerebral hemispheres are longer and narrower than in the cowardly Gudgeon."

The organ of smell in fishes has no connection with the mouth, and is in no way connected with respiration, as in higher animals. In the Lamprey and Hag (*Mycine*) it is single, but in all other fishes there are two olfactory organs. In osseous fishes these organs are placed at the sides of the snout. The Wrasses have a single opening for each nose sac, but in many fishes there are two, and then the anterior one is closed by a valve or circular muscle, and the posterior one is open. In the Sharks and Skates the nasal cavities are on the under side of the snout, and here the single wide opening is defended by a valve. The organs of sight in fishes are marked by a few peculiarities; thus, there is no lachrymal gland, the eyes apparently being sufficiently moistened by contact with the water. In the Hag and some other fishes the eye is a mere speck coated with dark pigment, but, as a rule, in osseous fishes the eyes are large, and are especially conspicuous in the Sun-fish. The crystalline lens is large and firm; the fibres which form it usually converge to two poles, like the meridians on a globe, but in the Salmon tribe and Sharks they converge to a line on each side. It was found by Sir David Brewster that the fibres of the crystalline lens in the Cod are locked together by teeth, like those on cog-wheels. He calculated that in the eyes of a Cod there are five millions of fibres, on which there are sixty-two thousand five hundred millions of these teeth, and yet in the living animal the organ is perfectly transparent. The pupil of the eye is usually round, but in many Sharks it is elliptical, and in the genus *Galeus* it is four-sided. In the Skates and flat fish a remarkable fringed process is connected with the upper margin of the pupil, and is capable of being let down and drawn up like a curtain, to regulate the quantity of light admitted to the eye. This would seem an arrangement to supplement the feeble contraction of the iris in fishes. In the Sharks and Sun-fish the eye is contained

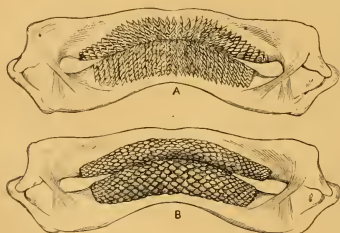
in a hollow cartilaginous sheath, but usually the sheath is formed of two hemispherical cups, which are sometimes cartilaginous and sometimes bony. There is often a good deal of fat between the outer sclerotic layer and the more vital internal parts of the eye. In the fresh-water genus *Anableps* the cornea is divided by an opaque horizontal line, on each side of which the iris is perforated by a pupil. The muscles which move the eyes of fishes correspond with those of man, and are usually six in number.

The organ of hearing is well developed in all fishes; the membranous labyrinth in the Lamprey has only two semicircular canals, and in the *Myxine* there is only one of these canals, but in all other fishes there are three, as in higher animals; they communicate with a vestibule, in which are contained the bony plates called otoliths; there are usually two of these flattened, somewhat oval organs, and one is larger than the other. But in a good many fishes, such as the *Plectognathi* and *Lophobranchiates*, the otoliths are represented by calcareous dust. No fish possesses a cochlea or a true tympanic membrane, but sometimes there is a connection between the labyrinth of the ear and the air-bladder, made by a chain of small bones. In the Loach the air-bladder is exceedingly small, extending under only two vertebrae, and is united with the head in this way. The external ears in the Skate are on the top of the head.

Closely allied to the organs of sense must be classed the electric organs of fishes, though the electric faculty is developed in very few genera. The best known of these are the *Torpedo* and the Electric Eel (*Gymnotus*), though less powerful electric organs exist in various species of *Malapterurus*, and are said to exist in *Trichiurus*, *Gymnarchus*, and a species of *Tetrodon*. In the *Torpedo* there are two electric organs; in the Electric *Gymnotus* there are two on each side of the body, where they occupy almost the whole of the lower half of the trunk, and are arranged on the upper and lower sides of the body. The electric organs are relatively larger in the *Gymnotus*, but their electric power is less. In the *Malapterurus electricus* the electric organ lies beneath the skin, and invests the whole body, with the exception of the head and fins. The electric organ is here divided into minute lozenge-shaped cells, so that the fish is protected by an electric coat, but the shock from it is comparatively feeble. In the genus *Mormyrus* a gelatinous organ placed on each side of the tail was formerly believed to be electric.

The teeth of fishes present a remarkable variety in their forms and numbers. Sir Rich. Owen remarks that the *Lophobranchii* are toothless, as are the Sturgeon, the Paddle-fish, and *Ammocetes*,

which is the larval form of the Lamprey, requiring four years for its development. The *Myxine* has a single-pointed tooth in the roof of the mouth, and two serrated dental plates upon the tongue. The Tench has one grinding-tooth on the occiput, opposed to which are two jaws in the pharynx below which bear teeth. In the genus *Chimæra* the teeth in the maxillary bones are confluent into two pairs, and there are two teeth in the mandible, but in the Siluroids and many other fishes the mouth is crowded with teeth. A large number of fishes have conical teeth; several of the Rays, like *Myliobates*, have the teeth arranged like a tessellated pavement. In the genus *Citharus* the teeth bifurcate at their extremities; in the genus



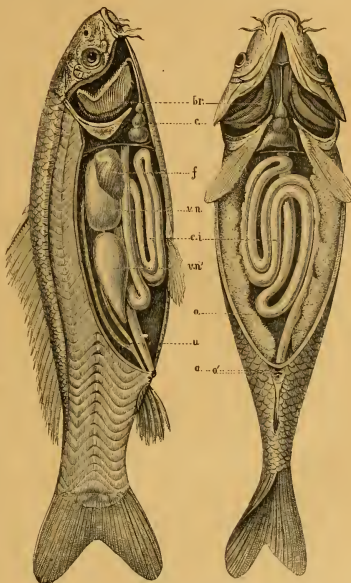
JAWS OF MALE (A) AND OF FEMALE (B) SKATE.

Platax they divide into three points. Sometimes there are hemispherical teeth arranged like a pavement, as in the Wrasse. The rarest position for teeth in a fish is upon the maxillary bone, though they are developed there in Salmon and Herrings, and some Ganoids. In many fishes the teeth are blended with the jaw; in Sharks their broad bases are usually attached by ligament; in the remarkable snout of the Saw-fish organs like teeth are implanted in sockets. Sometimes, as in the Wolf-fish (*Anarrhichas*), the front teeth are adapted for grasping shells, while the back teeth are fitted for crushing them. In all fishes the teeth are shed and renewed many times during the

whole duration of their lives; the only teeth which are retained permanently being those in the rostrum of *Pristis*, the dental masses of *Chimaera*, and a few others.

The lips of fishes are not much developed; in Sharks and Rays they are supported by cartilages. In the Cod there are fringed filaments between the lips and the teeth, and in several fishes there are tentacles attached to the lips, which assist in selecting food. There are no proper salivary glands in fishes, and the tonsils are entirely absent. The alimentary canal is usually short and large; in the genus *Lepidosiren* it is almost straight. The front part, termed the oesophagus, is a funnel-shaped canal coated with a strong muscular substance, so that it grasps the food and passes it downward into the stomach. In many fishes the pneumatic duct from the air-bladder opens into the oesophagus, and in the Ganoid fishes the entrance to this canal is controlled by muscles. The stomach is usually a large simple cavity, with a capacious inlet and a small outlet. Sir R. Owen defines two kinds of stomach in fishes: first, the enlarged bent tube seen in the Cod, Salmon, Teuch, Sturgeon, and most Sharks; and secondly, the form seen in the Perch, Gurnards, Smelts, Pike, Herring, Sprat, and Eel, in which the stomach forms a sort of pouch. It is rare for the stomach to be globular, but this condition is seen in the genus *Mormyrus*. The stomach takes on some of the characters of a gizzard, and in several fishes this organ is more or less divided into two or three chambers. The juice secreted by this organ has a rapid action on food, and it sometimes happens that the part of an animal contained in the stomach is dissolved, while the part which remained in the oesophagus is entire. Fishes disgorge the indigestible part of their food, and when caught frequently eject the animals they have swallowed. The intestine beyond the stomach is often short and simple. Round its commencement in most osseous fishes there are a number of slender pouches, which represent the sweetbread or pancreas of higher animals, but in the Lamprey and Hag there is no trace of a pancreas, and in a few fishes there is only a single filament to represent it; in the Turbot there are but two, and in the Perch three; in the Sprat there are as many as nine, but in the Salmon they are more numerous, and extend along the whole length of the first part of the small intestine, which is technically called the duodenum. In the Whiting this organ forms a fringe like a collar around the beginning of the intestine, and in the Sturgeon the pancreas becomes more compact, and pours its secretion into the intestine by a single wide duct. Sometimes the pancreas is heavier than the liver.

The liver in fishes is generally large, and consists of two lobes; it is soft, and usually yellowish-brown, but varies in colour in different fishes, being sometimes white, yellow, orange, green, bright red, and occasionally nearly black. It is an organ in which much of the oil of the body becomes accumulated, though fat fishes have very little oil in the liver. The liver varies in form with the shape of the body, being broad in the Rays and long in the Eels. It is greatly divided in the Tunny.



INTERNAL ANATOMY OF THE CARP.

br, Branchiae, or Gills; c, Heart; f, Liver; v.n., v.n', Swimming Bladder; ci, Intestinal Canal; o, Ovaries; u, Urethra; a, Anus; a', Oviduct.

As a rule, there is a gall-bladder, but it is frequently absent; it is very small in the Rays, and is sometimes entirely separated from the liver, as in *Lophius*. The bile enters the small intestine near the stomach. The internal surface of the small intestine is usually smooth, but in the Herring it shows slight transverse folds, in the Sturgeon it is divided up into cells, and in the Sun-fish it is lined with little tubes called villi, which absorb the nutriment from the food. The large intestine is straight, and in the Ganoid fishes, Mud-fishes, Sharks, and Rays terminates in a remarkable spiral coil. Though the small intestine is coiled up spirally in the Sword-fish, the coils are not in contact, but in the cartilaginous fishes there is usually a spiral channel which winds around many times. In the Fox Shark there are thirty-four of these turns; at the end of the intestine the membrane lining the valve is deeply honey-combed. Evidence of its existence in fossil fishes is found in the spirally-formed coprolites or petrified faeces which are met with in many of the geological formations.

The organs for purifying the blood, by separating from it the waste products, are different from the kidneys of higher animals, and correspond to organs which exist only in the embryo, and are known to anatomists as Wolffian bodies. Their function, however, is the same in fishes as that of kidneys in other animals. In most bony fishes the kidneys are long and narrow, and extend along the abdomen firmly attached to the vertebrae. The tissue forming them is usually of a reddish tinge; it is soft and spongy, and supplied with arteries from the abdominal aorta, which form the minute globular secreting organs termed Malpighian capsules, similar to those which abound in the outer layer of the kidney in higher vertebrates. Sometimes two ureters lead from the kidney and enter a urinary bladder, but occasionally, as in the Herring, there is only one ureter, and in this and several other fishes the bladder is wanting. It is largest in those fishes in which the air-bladder does not exist. The kidneys are long and narrow in the Ganoid fishes, and compact and generally lobulated in the cartilaginous fishes.

The air-bladder is found in most osseous fishes; it extends along the back of the abdomen, below the kidneys, and is prolonged in some fishes below the caudal vertebrae, nearly to the end of the tail.



SWIMMING BLADDER OF CARP.

Its varieties of form are very singular: it is sometimes divided lengthwise into two bladders, but much more frequently divided crosswise into two compartments which communicate with each other. In the Silurid fish *Pangasius* the air-bladder is said to be divided into four portions longitudinally. Sometimes the air-bladder develops blind processes: in certain cases from the fore part, in others from the hind part, and

occasionally from both ends. In the family Scianidae the air-bladder often has numerous lateral branches which themselves ramify into digit-like processes. In some species of the genus *Gadus* processes given off from the air-bladder line excavations in the transverse processes of the abdominal vertebrae, thus, as Professor Owen has pointed out, foreshadowing the pneumatic condition of the bones in birds. In other fishes—such as *Callichthys lucida*—the air-bladder is even more singularly developed, since its many branches form a covering round the abdominal viscera. The wall of the air-bladder is often shining and silvery; occasionally the interior is subdivided into small cells: this condition may be seen in the genera *Erythrinus* and *Amia*. The air-bladder here seems to be taking on some of the characters of a lung, and in *Lepidosiren* and *Ceratodus* the transition is completed. The air-bladder is entirely wanting in the Sharks, Rays, Chimæra, Lampreys, Flat-fish, and other forms, several of which, like the Angler, live habitually at the bottom of the sea. The duct connecting the air-bladder with the œsophagus seems to be the rudiment of the trachea, though it does not always open into the anterior end of the air-bladder. In most fresh-water fishes the air-bladder is filled chiefly with nitrogen gas, mixed with a little oxygen, while in sea fishes the gas is chiefly oxygen, with a little nitrogen. Occasionally, when fishes are brought up from great depths, the air-bladder expands, and forces the internal organs out of the mouth. In the Gurnards the air-bladder assists in the production of sound, so that these fishes may be said to possess a voice.

The blood in fishes is red, but small in quantity. The red blood discs usually have an elliptical shape, and are largest in the Sharks. In the Lamprey the red corpuscles are nearly

circular; there are also, as in higher and lower animals, larger white corpuscles. The greatest quantity of blood is found in the Tunny, which, according to Dr. Davy, is a warm-blooded animal, with a temperature as high as that of most mammals. The lowest type of fish—the Lancelet—has no true heart, but a blood-vessel which pulsates very slowly, there being but one beat in a minute, while in most fishes the number of beats in a minute varies from twenty to twenty-four. The heart is relatively small in all fishes, and even in Sharks and Rays is only about one-thousandth part of the weight of the body, which is about one-half of its relative size in reptiles. This organ in fishes consists chiefly of two parts, which correspond to the pulmonary side only of the heart in man, and are named the auricle and ventricle. It is usually placed in the throat, in a cavity partitioned off by a fixed tendinous diaphragm. The auricle, which is thin and relatively large, receives its blood from a sinus, formed by the union of the veins which bring the blood from the body. Each aperture of the auricle is guarded with strong valves. The ventricle is small and muscular; its form is pyramidal in the Ganoid fishes, lozenge-shaped in the Pike, oval in the genus *Lophius*. It opens by means of valves into an enlarged muscular portion of the branchial artery, which is called the *bulbus arteriosus*; this contracts like the ventricle, and assists in forcing the blood into the gills. In the interior of this organ there is an elaborate system of valves, which are arranged in two rows in most Sharks, and form three, or even six, rows in Ganoids. After the blood has passed through the gills the vessels unite and form an artery, which extends under the vertebrae along the length of the body.

The modifications of the gills are sufficiently important to give names to some of the great group of fishes, such as *Marsipobranchii*, *Lophobranchii*, and *Elasmobranchii*. In the Hag, which is an example of the *Marsupial* type of gill, there are six little branchial sacs on each side; these are produced into short tubes on both sides, and these tubes are prolonged into a longitudinal canal, which extends backward, and carries the stream of water away from the gills on each side, terminating on the ventral surface on each side of a third larger opening, which admits water in the same way into the branchial sacs. In the *Lophobranchii*, which comprise the *Pipe-fishes*, the gills, instead of having the comb-like form usual among fishes, form a double series of nearly circular tufts. In the *Elasmobranchii* the gills are arranged side by side, so as to suggest the idea of plates with openings between them, which are usually long slits, as may be seen in the Sharks and Rays. The branchial chamber is largest in those fishes in which the outlet from it is small. In some of the Eels these outlets approximate close together on the under side of the head; in the Sturgeons and Ganoids there is a canal leading from the fore part of each side of the branchial chamber to the top of the head. These canals are called *spiracles*. In all the osseous fishes there is only one visible outlet to the gills on each side. Each leaflet of the gills usually consists of a pair of processes, but in some osseous fishes some of the branchial arches support only one series of these leaflets.

Many genera, like *Zeus* and *Polypterus*, have on each side three double gills and one uniserial. In the genera *Lophius* and *Diodon* there are three bi-serial gills; in *Lepidosiren* there are bi-serial gills and one uniserial. The number of plates on a single leaflet may range from as few as fifty-five in the Gudgeon to sixteen hundred in the Sturgeon. It is interesting to remark that in the embryonic osseous fish the five interspaces between the hyoid arch and the five branchial arches are exposed on the sides of the head, and that subsequently the branchiostegal appendages are developed, and a single branchial outlet results from the formation and backward growth of the operculum. Owen remarks that the mechanism of breathing in fishes differs from that of swallowing only in the streams of water not entering the gullet, and being diverted to the branchial slits on each side of the pharynx. The bones which cover the gills are collectively known as the operculum. This organ is connected with the skull by means of the *hyo-mandibular* bone, which also supports the jaws. The principal bone is named the operculum, below which is the sub-operculum, and below this the inter-operculum. In front of these is the pre-operculum.

It is necessary to complete our knowledge of fishes to carefully examine the characters of their fins. In the majority of fishes there are five kinds of fins, which are named pectoral, ventral, anal, dorsal, and caudal (see p. 3). The pectoral and ventral correspond to the arms and legs of higher animals, and when they exist they are always in pairs. The other fins are single or unpaired, and are entirely unrepresented in the skeletons of higher Vertebrates. The pectoral fins are almost always present,

though they are wanting in Lampreys. They are always formed of flexible rays, which are generally branched. The first ray is sometimes strong and spiny, and among Siluroid fishes is barbed on one or both sides. In the Flying-fish, the Tunny family, and the Rays the pectoral fin attains its greatest development, and is usually pointed; but, as Swainson has remarked, families which live in rivers and lakes have the pectoral fins rounded. The Gurnards have the pectorals greatly developed, but their fins are nearly always rounded, though they may be partially cleft or digitate; when broad at the base they usually extend under the throat. The cleft fins are seen in the genus *Cephalacanthus*; the digitated pectorals are seen in the Gurnards. The pectoral fins of Sharks are generally large. In the Flat-fish they are smaller than in any other member of the class. In the family Pediculati, or Fish Frogs, the pectoral fins perform the office of feet. The ventral fins are less important in swimming than the pectoral; they are generally of small size, though in the genus *Zens* they are larger. In the Eel group they are entirely absent. The position of these fins varies, being placed under the throat in the Star-gazer (*Uranoscopus*), while in the genus *Polypterus* they are near the base of the caudal fin. When the pectoral is rounded the ventral is usually rounded too, though this correspondence between the fins is by no means universal. Some fishes possess fins which are capable of adhesion by suction. The family *Gobiesocidae* has circular concave discs on the breast and belly, which extend between the pectoral and ventral fins. In the genus *Regalecus*, or Ribbon Fish, the ventral fins have the rays broadened at the extremity so as to resemble oars. The dorsal fin is rarely altogether wanting, though it is absent from *Gymnotus branchiurus*. The dorsal fin is generally composed of a number of bony rays, placed successively behind each other and connected by a membrane. Frequently there are two dorsal fins. In the soft-finned group the hinder dorsal fin is generally formed of fat. The *Polypterus* offers a remarkable type of dorsal fin, in that the fin is divided into a large number of finlets, which reach from the head backwards. The dorsal fins are very thick in cartilaginous fishes, and are thinner in the spiny-finned osseous fishes. A few genera have three dorsal fins, as may be seen in the Cod. The rays forming the fin are sometimes slender bones, are sometimes jointed, and sometimes branched. The branched spines are well seen in genera allied to the Mackerel. The common Stickleback furnishes a familiar example of the spiny modification of the fin. Sometimes the dorsal fins are triangular, and sometimes they are broad, and occasionally end in filaments. In a good many fishes, especially among the Eels, the dorsal fin unites with the caudal fin. The anal fin corresponds more or less to the dorsal, only it is placed longitudinally on the inferior margin of the body, behind the vent. Sometimes, as in *Gymnotus*, it extends nearly the whole length of the fish. The caudal fin is the great organ of motion; it usually consists of two symmetrical lobes, which are made up of a number of radiating rays. The terminal part of the notochord, or spinal column, as the case may be, bends upward, so that a larger number of the fin rays lie below than above it; hence, although the tail in the bony fishes is homocercal in form, it is heterocercal or unsymmetrical in structure. In the Tunny the fin rays are attached to the sides of a somewhat fan-shaped terminal bone, and in these fishes the tail is more deeply forked than in any other. The caudal fin presents every modification in form; it is lanceolate in the Indian Gobies, but is sometimes rounded, or truncate, oblong-oval, even, and variously forked. Occasionally the caudal fin is indistinct; it is but little developed in the Rays, and there is no terminal fin in the Pipe-fish or in *Chimæra*. In one genus the fin is placed vertically upon the extremity of the tail. The analogy of fins to wings is evidenced by their performing the office of wings in the Flying-fishes. One of the best characters by which the genera and species of fishes may be identified and defined is furnished by the number of rays in the several fins. In most cases these are written in formule, in which the number of rays in a fin follows its initial letter.

All fishes have the sexes distinct. The male organs constitute the well-known soft roe, while the ovary of the female is hard roe. In the female the oviduct has its outlet usually in front of the urethra, and behind the anus. In the Californian genus *Ditrema* the young reach a relatively large size, and are packed in the body of the parent as close as Herrings in a barrel. The oviparous cartilaginous fishes are remarkable for the large size of the egg, and the strength of the case in which it is contained. In Sharks of the genus *Cestracion* this egg-case is spiral; and in the southern *Chimæra* it has an oval form with a fringed margin. The males of *Chimeroid* fishes and *Plagiostomes* are armed with remarkable organs termed claspers, which are attached to the bases of the ventral fins. A few fishes build nests.

The following sketch of the classification used in this article may be convenient for reference :—

CLASS PISCES.

DIVISION I.—PALÆICHTHYES (FISHES OF ANCIENT TYPES).

ORDER I.—DIPNOI (MUD-FISHES). Family—Sirenoidei.

ORDER II.—GANOIDEI (FISHES WITH BONY SCALES).

Family I.—Amiidae (North American Mud-fish). II.—Polypteridae (Nile Pike). III.—Lepidosteidae (Bony Pike).

ORDER III.—HOLOCEPHALA. Family.—Chimaeride (Chumera).

ORDER IV.—PLAGIOSTOMATA (FISHES WITH OBLIQUE MOUTHS).

SUB-ORDER I.—SELACHOIDEI (SHARKS).

Family I.—Carchariidae (Blue Shark). II.—Lamnidae (Porbeagle). III.—Rhinochimaeridae. IV.—Notidanidae (Grey Shark). V.—Squalidae (Dog-fishes). VI.—Cestraciontidae (Cestracion). VII.—Spinacidae (Piked Dog). VIII.—Rhinochimaeridae. IX.—Pristigasteridae (Shark-like Saw-fish).

SUB-ORDER II.—BATOIDEI (RAYS).

Family I.—Pristigasteridae (Skate-like Saw-fish). II.—Rhinochimaeridae. III.—Torpedinidae (Electric Rays). IV.—Rajidae (Skates). V.—Trygonidae (Sting Rays). VI.—Myliobatidae (Eagle Ray).

ORDER V.—CHONDROSTEI. Family I.—Acipenseridae (Sturgeons). II.—Polyodontidae.

DIVISION II.—TELEOSTEI (BONY FISHES).

ORDER I.—PLECTOGNATHI (FISHES WITH JAWS UNITED).

Family I.—Sclerodermi (File-fish and Trunk-fish). II.—Gymnodontes (Diodon and Sun-fish).

ORDER II.—LOPHOBANCHII (FISHES WITH TUFTED GILLS).

Family I.—Solenostomidae. II.—Syngnathidae (Pipe-fish and Sea-horses).

ORDER III.—ANACANTHINI (SOFT-FINNED FISHES).

SUB-ORDER I.—GADOIDEI.

Family I.—Gadidae. II.—Lycodidae. III.—Gadidae (Cod). IV.—Ophiidae (Sand-eels). V.—Macruridae. VI.—Ateleopodidae.

SUB-ORDER II.—PLEURONECTOIDEI.

Family VII.—Pleuronectidae (Flat Fishes).

ORDER IV.—PHARYNGOGNATHI (FISHES WITH JAWS IN THE THROAT).

Family I.—Pomacentridae. II.—Labridae (Wrasse). III.—Embiotocidae. IV.—Gerridae. V.—Chromidae.

ORDER V.—ACANTHOPTERYGII (SPINY-FINNED FISHES).

Family I.—Percidae (Perch). II.—Pristigasteridae. III.—Squamipinnæ. IV.—Nandidae. V.—Mullidae (Red Mullet). VI.—Sparidae. VII.—Hoplunnathidae. VIII.—Cirrhitidae. IX.—Scorpenina. X.—Polycentridae. XI.—Teuthididae. XII.—Berytidae. XIII.—Kurtidae. XIV.—Polynemidae. XV.—Sciaenidae. XVI.—Xiphidae. XVII.—Trichuridae (Hairtails). XVIII.—Acronuridae. XIX.—Carangidae. XX.—Cyttina. XXI.—Stromateina. XXII.—Coryphæna. XXIII.—Nomeina. XXIV.—Seombrina. XXV.—Trachinidae. XXVI.—Malacanthidae. XXVII.—Batrachidae. XXVIII.—Pediculati (Sea-devil). XXIX.—Cottina (Gurnards). XXX.—Cataphracti (Armed Bull-head). XXXI.—Comephoridae. XXXII.—Discoboli (Lump suckers). XXXIII.—Gobiidae. XXXIV.—Oxudercidae. XXXV.—Cepolidae. XXXVI.—Trichonotidae. XXXVII.—Heterolepidina. XXXVIII.—Bleniidae. XXXIX.—Acanthoclinidae. XL.—Mastacembelidae. XLI.—Sphyræna. XLII.—Atherinidae. XLIII.—Mugilidae (Grey Mullet). XLIV.—Gasterosteidae (Sticklebacks). XLV.—Fistulariidae. XLVI.—Centriscidae. XLVII.—Gobiocidae (Suckers). XLVIII.—Psychrolutidae. XLIX.—Ophiocephalidae. L.—Labyrinthici (Climbing Perch). LI.—Luciocephalidae. LII.—Aphredoderidae. LIII.—Lophotidae. LIV.—Trachypteridae. LV.—Notacanthi.

ORDER VI.—PHYSOSTOMI (FISHES WITH THE AIR-BLADDER OPENING INTO THE MOUTH).

Family I.—Siluridae. II.—Characinae. III.—Haplochromidae. IV.—Sternopygidae. V.—Scopelidae. VI.—Stomiidae. VII.—Salmonidae (Salmon). VIII.—Percopsidae. IX.—Galaxiidae. X.—Mormyridae. XI.—Gymnarchidae. XII.—Esocidae (Pike). XIII.—Umbridae. XIV.—Scombreidae. XV.—Cyprinodontidae. XVI.—Heteropogon. XVII.—Cyprinidae (Carp). XVIII.—Gonorhynchidae. XIX.—Hyodontidae. XX.—Osteoglossidae. XXI.—Clupeidae (Herrings). XXII.—Chirocentridae. XXIII.—Alepocephalidae. XXIV.—Notopteridae. XXV.—Halosauridae. XXVI.—Gymnotidae (Electric Eel). XXVII.—Symbranchidae. XXVIII.—Muraenidae (Eels). XXIX.—Pegasiidae.

DIVISION III.—CYCLOSTOMATA (FISHES WITH A CIRCULAR MOUTH).

ORDER.—MARSIPOBRANCHII. Family I.—Petromyzontidae (Lamprey). II.—Myxiniidae (Hag).

DIVISION IV.—LEPTOCARDII (FISHES WITH A THIN HEART).

ORDER.—PHARYNGOBRANCHII. Family.—Cirrostromi (Lancelet).

CHAPTER II.

THE PALÆICHTHYES, OR FISHES OF ANCIENT TYPES.

DIPNOI, OR MUD-FISHES—Why this Order is Interesting—THE AFRICAN MUD-FISH—THE SOUTH AMERICAN MUD-FISH—THE GENUS CERATODUS—GANOIDEI, OR FISHES WITH BONY SCALES—THE AMIIDE—*Amia calva*—THE BONY PIKE OF THE NILE—THE AMERICAN BONY PIKE—Its Remarkable Characters—HOLOCEPHALA—The *Chimera monstrosa*—The Genus *Callorhynchus*—PLAGIOSTOMATA—The Sharks and Rays—SELACHOIDEI—THE BLUE SHARK—Its Habits—Muscular Vitality—Economic Uses—Other Genera—The Common British Torpedo—THE HAMMER-HEADED SHARK—THE SMOOTH HOUND—The Porbeagle, or the Beamaris Shark—THE THRESHER, OR FOX SHARK—THE PARKING SHARK—Enormous Proportions—The “Sea Serpent”—Habits—Fisheries—Characters—THE SIX-GILLED SHARK—THE DOG FISHES—The Nurse Hound and the Rough Hound—Their Eggs and Egg-purses—“Sea-dog Soup”—The Black-mouthed Dog-fish—Cestracion—THE PICKED DOG-FISH—Why so Named—Characters—Various Forms—THE SPINOUS SHARK—THE MONK-FISH—The Indian Shark Oil Industry—BATOIDEI, THE RAYS—Distinctive Features—THE PRISTIDE—THE RHINOBTIDE—THE TORPEDINIDE—THE GENUS TORPEDO—Strength of the Shock—The Electric Organs—Characters—Other Forms—THE RAYS—Characters—The True Skate—Fishery—THE LONG-NOSED SKATE—THE BORDERED RAY—THE SHAGREEN RAY—THE HOMELYN RAY—THE THORNBACK—THE STING RAYS—Growth of its “Spine”—Various Species—THE EAGLE RAY—THE OX RAY, OR SEA DEVIL—CHONDROSTEI—THE STURGEONS—Characters—Caviare—Fishery—Other Economic Uses—The Common Sturgeon—Article of Diet—The *Acipenser huso*—The Sterlet—The Paddle-fish.

DIVISION I.—PALÆICHTHYES.

ORDER I.—DIPNOI.—MUD-FISHES.

This small group of fishes has more than ordinary interest, from the circumstance that it comprises surviving representatives of a large fish fauna, now entirely extinct, which abounded in the early periods of the earth's history. And yet, instead of presenting, as might have been expected, characters of immature or imperfectly-developed forms, these fishes are the only ones which make an appreciable approximation in structure to the Amphibia.

FAMILY SIRENOIDEI.

There are only three genera known—*Protopterus*, limited to Africa, *Lepidosiren* to South America, and *Ceratodus* to Australia.

GENUS PROTOPTERUS.—THE AFRICAN MUD-FISH.

But one species is known, the *Protopterus annectans*, which has an Eel-like form, grows to a length of three feet, and is found in the Nile, the Zambesi, and the Gambia. It has been brought alive to Great Britain enclosed in balls of hardened clay, in which the fish hibernates and remains torpid during many months of the year, with a small hole in the clay at each end to admit the air. They are abundant in the rice-fields, where they are dug out of the mud by the natives, who regard them as a delicacy.

The examples originally described by Sir R. Owen were twelve or thirteen inches long, and measured about four inches and a half round the body. The head was two inches long, and the distance from the pectoral to the ventral fin five inches and a half. The muzzle is blunt, and the head gradually enlarges towards the gill-opening, which is just in front of the base of the pectoral fin or fore-limb. A line of mucous pores surrounds each eye, and from this the lateral line commences, and is prolonged down the body to the end of the tail, making a slight downward curve towards the ventral fins. There is a membranous dorsal fin. The body is sheathed in scales of the cycloid pattern, which are arranged in about sixteen longitudinal series on each side of the body. Each scale is marked by a number of canals, which radiate from a centre near the posterior edge, and are connected by cross canals. The bones are green, like those of the common Garfish. The vertebral column retains the primitive condition seen in the early stage of development of all animals in which the continuous cylindrical, somewhat gelatinous rod, which is termed the notochord persists, in the position which usually becomes occupied by the bodies of the vertebrae, a change which is brought about by the deposition within the notochord of the salts of lime which form bony matter. Here the notochord has merely an external sheath of ligament, except towards the tail, where it becomes somewhat cartilaginous. The neural arches, however, which cover the spinal cord, are converted into bone, and are prolonged into neural spines, each of which articulates with a bone above, which bones form the base of the dorsal fin. There are thirty-six pairs of simple ribs, which are all of

about the same length, and all short; they are bent downward in the tail, so as to form an inferior arch like the neural arch, after the manner which is usual in fishes. The skull is penetrated by the cranial end of the notochord, though it there becomes ossified. The skull is divided into distinct cranial segments, each formed of bones. The lower jaw consists of two pieces—a dentary bone in front and the articular bone behind. The jaws are armed with two slender conical teeth on the pre-maxillary bones, and with a strong dental plate on both the lower and upper sides of the mouth. These teeth are marked with ridges, and were originally compared by Sir R. Owen to the teeth of *Ceratodus*—then supposed to be extinct—and the teeth of *Chimæra*. There are no teeth on the bones of the palate.

The intestine is straight and short; it terminates in a spiral valve formed of six gyrations. The



AFRICAN MUD-FISH.

vent does not open in the middle line of the body. There is no trace of a pancreas or spleen, but the dark-brown liver has a gall-bladder in a notch of its left margin. The bile is conveyed by a duct into the intestine. The brain closely resembles that of Amphibians. This genus is distinguished by possessing six branchial arches with five intervening clefts, and has three small branchial appendages above the small gill-opening. The air-bladder has a longitudinal partition, so as to divide it into two elongated sacs, which are supplied with venous blood from a pulmonary artery. Each of these sacs is divided into cells, which are more numerous in the fore-part of the bladder than in the hinder part. It is by means of these incipient lungs that respiration is carried on during the dry months, when the animals live out of water. Air is introduced directly into the air-bladder, and the opening of the duct from it into the œsophagus is kept distended by a cartilage like a rudimentary larynx. When, in the wet season, the *Lepidosiren* resumes life as a fish, the branchial circulation again goes on vigorously, but the animal still rises to the surface and swallows air.

The *Protopterus* exhibits the simplest form of limb which is known. The pectoral and ventral

fins or limb each consists of a single ray which tapers to a point, and is jointed much like a single-jointed fin-ray of an ordinary fish. These limbs are attached to arches which represent, in an imperfect condition, the corresponding pectoral and pelvic girdles of osseous fishes and amphibians.

GENUS LEPIDOSIREN.—THE SOUTH AMERICAN MUD-FISH.

Lepidosiren was discovered in the River Amazon. It so closely resembles *Protopterus* in the form of its body that for a long time the two species were placed together in the same genus. The *Lepidosiren paradoxa*, however, has but five branchial arches with four intervening clefts, has no trace of the external branchial appendages, has no fringe to the pectoral and ventral filaments, such as is seen in *Protopterus*, and has about fifty-five pairs of ribs. In this animal the eyes are small, and the skin passes over them. The species reaches a length of three feet, and when the waters dry up on the tributaries of the Amazons the fishes plunge into the mud.

Sir Rich. Owen remarks that *Lepidosiren* is proved to be a fish not by its gills, nor by its air-bladder, nor by its spiral intestine, nor by its unossified skeleton, nor by its extremities, nor by its eyes, nor by its ears, but simply by its nose. For the organ of smell in every fish is a shut sac, communicating only with the external surface; while in every reptile it is a canal with both an external and an internal opening. So that we arrive at the unexpected result that a reptile is not characterised by its lungs, nor a fish by its gills.

THE GENUS CERATODUS.

A few years ago Mr. Gerard Krefft announced that there was still living in the rivers of Queensland, in the north-east of Australia, a fish with teeth which so closely resembled those of the fossil *Ceratodus* from the older Secondary rocks, that he was compelled to refer it to the same genus. It is stated to occur abundantly in most of the rivers, and is known locally among Europeans as the Flat-head. At night it is believed to leave the streams, and go out among the reeds and rushes on the flats, which are left uncovered at low tide, and it is said often to be heard moving on still nights on the banks of the River Mary. In some localities it goes up the river only as far as the water remains brackish, but other specimens have been captured in fresh water thirty miles inland. Individuals are said sometimes to reach a length of six feet. The intestines are always found crammed full of dead leaves, which belong to the natural orders of plants *Myrtaceæ* and *Graminæ*. In external shape the *Ceratodus* has a close likeness to the *Lepidosiren*, except that it more nearly resembles an ordinary fish, has stouter paddles, and large scales covering the body. The head is longer than it is wide, but broad and flattened, with a short snout. Its upper surface is covered with a thick skin pierced by small pores. The gill-cover and throat are clothed with scales like those on the body; the eye, which is small, is near to the snout; the corners of the mouth are in front of the eyes, and the lips are thick and soft. The whole body is covered with large scales, which have faint concentric lines of growth, but towards the end of the tail the scales become rapidly smaller, and small scales cover nearly the whole of the terminal fin. The central portions of the fin-paddles are also covered with small scales. The lateral line is marked in the usual way; from the head to the region of the vent there are twenty-two large perforated scales in this line, and beyond that point there are about seventeen smaller scales. In the middle region the body is encircled by eighteen or twenty rows of scales, of which only one-third are above the lateral lines. The limbs, like the tail, vary a good deal in appearance; they taper to a fine point, the front pair being longer than the hinder pair, which latter are given off just in front of the vent. Nearly all the skeleton is cartilaginous, but in some regions of the skull the cartilage is sheathed in thin bony tissue. Dr. Günther describes it as a complete inner cartilaginous capsule, covered with an incomplete outer osseous case, to which some cartilaginous elements are attached. The skeleton of the branchial apparatus is formed of fine arches, and though entirely cartilaginous, is similar to that of ordinary bony fishes. The vertebral column is remarkable for retaining a condition which is usually found only in the early embryonic development of the higher vertebrates, for there is no complete division of the central gelatinous rod called the notochord into separate vertebrae. Upon this notochord are developed about sixty-eight sets of arches, which extend above it to enclose the spinal cord, and below to support the blood-vessels. Twenty-seven of the lower arches behind the head carry ribs. The teeth are fitted for

cutting and crushing. There is one pair of small teeth in the fore-part of the jaw which, from their position upon a bone called the vomer, are termed vomerine teeth; they meet each other at a right angle, which is directed forward. The other teeth are much larger, and are crossed by six strong ridges, which extend inward from the outer margin. Between these ridges are five notches. In a specimen three feet long this tooth is an inch and a quarter long and half an inch wide. The corresponding teeth in the lower jaw have a similar shape, and are so placed as to fit against the others and form an apparatus for grinding food. The hard parts of the fore-limb are entirely cartilaginous; the paddle is joined to the scapular arch by a cartilage which represents the humerus. A median row of cartilages of a quadrate form, twenty-six in number, extends the length of the limb, and on both sides of it rays are given off which diverge downward and outward. This type of fin is quite unparallelled, although the central series of cartilages may be compared to that of the Lepidodiren. Dr. Günther has compared the fin to the tail of an ordinary osseous fish; nor is the plan of structure very dissimilar to the tail of *Ceratodus* itself. The structure of the hind-limb is quite like that of the fore-limb, except that it is rather more symmetrical and is shorter. The intestine is nearly straight, and below the stomach is traversed throughout by a spiral valve, which may be compared to that of Sharks and Rays, and winds around nine times. But the most remarkable circumstance about this fish is the fact that it can breathe either by gills or by lungs, or simultaneously by both. The gills are not connected with spiracles, nor is there any true operculum. The lung is single, and is a wide sac which extends down the middle of the dorsal region, from one end of the abdominal cavity to the other. It is divided into about thirty compartments on each side, and in these the tissue presents much of the character which is usually seen in the lung of a reptile. It has a short duct terminating in a glottis, which opens on the ventral side of the gullet. The air is probably expelled from the lungs much as among reptiles—by the tissue contracting; and this is thought to account for the grunting noise heard at night when the fish are out of water. The species has been named *Ceratodus forsteri*.



CERATODUS. (After Günther.)

ORDER II.—GANOIDÆ, OR FISHES WITH BONY SCALES.

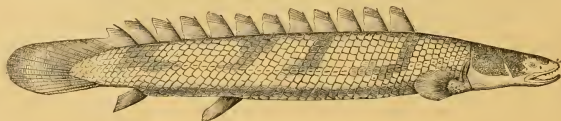
FAMILY I.—AMIIDÆ.—THE NORTH AMERICAN MUD-FISH.

The Ganoid fishes are a group fast verging on extinction, and are represented at the present day by three families, which include four genera and six species; but from the light which their structure throws on the fossil forms of both Primary and Secondary strata, no less than from some remarkable points of structure, they deserve notice. In the first family, Amiidæ, there is but one species—*Amia calva*, which is known as the Bow-fin of Lake Champlain, the Dog-fish of Lake Erie, the Marsh-fish of Canada, and is sometimes known as the Mud-fish. The body is long, compressed behind, and sub-cylindrical. The head is broad, with a short snout; the jaws are margined with an outer series of delicate sharp-pointed teeth, which are closely set, and there are patches of similar teeth on the vomer, palatine, and pterygoid bones. The lower jaw has a single row of

teeth. The tongue is covered with papillæ; the nostrils are prolonged into short tubes. The scales are of the cycloid pattern, and are sometimes covered with enamel; they are large, and marked with radiating lines, and are enveloped in a soft skin; those which occur in the lateral line are slightly elevated. The colour is dull, often dark greenish, with black spots and bands, and there is frequently a round black spot on the tail. The animal is covered with thick mucus. Its movements in the water are not very rapid. It feeds chiefly on fresh-water crustacea, is sometimes eaten by the Indians, and attains a length of about two feet. The vertebral column is chiefly remarkable for having intercalary vertebrae introduced in the tail. The first appears after the sixth caudal, and the last between the twenty-second and twenty-third caudal. These intercalary bones are entirely devoid of processes, and occasionally one or more of them may be absent. The end of the vertebral column is cartilaginous, and directed upward. The air-bladder is a large membranous sac divided anteriorly into two short horns; its internal appearance is compared to that of the lung of a serpent with cells in the anterior part which disappear towards the posterior end. It communicates with the œsophagus by a duct, and has a sort of glottis with an oblong opening. There are four gills; each arch is formed by a double row of leaflets; there are ten or twelve branchiostegal rays. The stomach forms a blind sac, diverging from the intestine; there are no pancreatic appendages; the liver has two lobes; and there is a rudimentary spiral valve at the termination of the intestine. This fish is limited to the fresh waters of the United States, and is especially met with in the great expanse of low-lying country between the Alleghanies and the Rocky Mountains, in the Mississippi, Northern lakes, and Middle States.

FAMILY II.—POLYPTERIDÆ.—THE BONY PIKE OF THE NILE.*

This is the type of a family which at the present day includes only two genera. *Polypterus* occurs throughout the tropical parts of Africa, especially in the Nile, Gaubia, and Senegal rivers, and other parts of the west coast. It is an elongated fish, with a short snout and somewhat cylindrical body. It is defended with lozenge-shaped ganoid scales. The species *Polypterus bichir* lives in the mud at the bottom of the rivers, where the fish crawl or walk like Seals by means of their fins. They swim with great rapidity, much in the manner of serpents. At the time of reproduction they are chiefly at the surface of the water. This fish presents an extraordinary appearance, from the way in which the dorsal fin is broken up into a succession of little finlets, which vary in number in the several varieties from eight to eighteen. The vertebrae are bi-concave, as in ordinary fishes, but the termination of the vertebral column is cartilaginous. The head is covered by enamel similar



POLYPTERUS.

to that which defends the scales of the trunk. From the lateral expansion of the bones of the head, this fish presents much the same sort of resemblance to a Chelonian that the head of the *Lepidosteus* has to that of a Crocodile. The ventral fins are well developed, and the anal fin is placed close to the lower margin of the caudal fin. The central portion of the fin in these fishes is fleshy, and covered with scales, so that the rays appear as a fringe around it. This character is met with in many of the fishes of the Old Red Sandstone, and Professor Huxley has proposed to unite them together under the name of Fringe-finned Fishes, or *Crossopterygida*. There are three bones between the fin-rays and the shoulder-girdle. The air-bladder is more simple than that of *Lepidosteus*; it consists of two sacs, which are cylindrical and unequal, but there are no internal cells in the bladder representing lung structure. There is, however, a duct from the two lobes opening into the œsophagus, and the opening is defended by a circular muscle. There are three and

* Genus *Polypterus*.

a-half pairs of gills, but no gill upon the operculum. There is a spiracle on each side of the parietal bone, covered by a bony plate. The branchiostegal rays are replaced by a single plate of bone. The stomach has no blind sac, there is one pancreatic appendage, and the intestine terminates in a spiral valve. There are fifty-one vertebrae in the abdomen and sixteen in the tail.

From Old Calabar there comes a remarkable fish closely allied to the Polypterus, which is named *Calamoichthys calabaricus*. It has a much more elongated form; the dorsal and ventral surfaces are parallel. There are about a hundred vertebrae in the abdomen and ten in the tail. The dorsal fin is represented by from nine to eleven finlets; the ventral fin is absent, and the small anal fin is placed at the hinder extremity of the body, immediately below the tail.

FAMILY III.—LEPIDOSTEIDÆ.—THE AMERICAN BONY PIKE.*

The Bony Pike, or Garfish, as it is often called, is one of the most distinctive of American types of fish-life. It is met with in the rivers and lakes of the basin of the St. Lawrence, in various parts of the United States, and in Mexico, and occurs in Cuba. American authors have distinguished more than twenty different species, which have been referred to several genera. Dr. Günther reduces these species to three—the *Lepidosteus viridis*, the *Lepidosteus platystomus*, and *Lepidosteus osseus*. These fishes swim with the greatest rapidity, darting through the lakes and rivers, and are able to pass through the most rapid currents, not excepting the rapids of Niagara. Their bodies are more flexible than those of ordinary fishes. Agassiz notices that the head moves freely on the neck, and may be indifferently wagged from side to side, or moved upward or down, movements which are impossible in other fishes. This mobility results from the remarkable mode of union of the vertebrae with each other. Instead of being cupped at each end there is a rounded articular surface in front, and a corresponding concavity behind. The vertebral column terminates in a small conical cartilaginous rod, which is directed to the upper margin of the tail, where it is only covered by the skin. The vertebrae have transverse processes, to which the ribs are articulated.



VERTEBRA OF THE
AMERICAN BONY PIKE.

The head has an armoured appearance, and is covered with furrows and rugosities, which are arranged in a definite manner; it is prolonged into jaws, which are large and long in proportion to the size of the hinder part of the head. The lower jaw is always rather shorter than the upper, and is formed of the same bones as occur in the jaws of Crocodiles and Lizards. The maxillaries are a series of bones joined together, end to end, so as to produce by their union a single long bone. The snout includes, besides the maxillaries, long nasal bones and some other bony elements. The fins unite with the skeleton, as in other osseous fishes. The pectoral fins are strongly developed. All the fin-rays are jointed. The air-bladder is placed as in other fishes; it communicates with the throat by a duct, which is guarded by a circular muscle. This organ is very long, and extends from the œsophagus to the hinder extremity of the body. It is forked in front, but is undivided in the greater part of its length, and sometimes there is a trace of a posterior bifurcation; it is said to be muscular, so as to be capable of contracting. Its internal surface is cellular, so that it presents some resemblance to the lungs of the lower reptiles and amphibians; but while air is breathed by this organ there are also gills, which are supported on four arches and have a bi-serial structure. The branchiostegal rays are three in number. The scales, next to the long jaws, are the most striking feature of the animal. They are lozenge-shaped, and arranged in more or less oblique series, so as to overlap each other, and form a close-fitting bony armour. In the middle of the belly the scales are heart-shaped. The external layer of the scales is always brilliant and shining, being formed of enamel, while the lower layer consists of bone. The scales are perforated by canals similar to the blood-vessels in bones, and the vessels passing through them carry blood to the skin. The lateral line is always straight. The colour of the back is brownish-yellow or greenish, sometimes with black spots. The young sometimes have a dark band at the sides, and generally a dark band in the median line of the back. The nasal pores are at the extremity of the snout, and the eyes are a moderate size. These fishes are extremely voracious; they often frequent shallow and reedy places and bask in the sun. They approach their prey slyly and sideways. The prey is held in the mouth

* Genus *Lepidosteus*.

and turned until placed in a proper position for being swallowed, when it is eaten in the same manner as food is taken by Lizards. The teeth are arranged in double rows, but are of unequal size. The larger teeth are in the lower jaw. The stomach and liver are both large, and the pancreas is in the usual position. The intestine has a rudimentary spiral valve. These fishes come to the surface for air. They attain a length of upwards of five feet. In the *Lepidosteus osseus* the second row of teeth in the upper jaw is found on the palatine bones in young specimens, but in the adult only minute teeth are to be seen in this position. In the *Lepidosteus viridis* the teeth on the palatine bone are larger, and similar to the strong teeth on the maxillary. The larger teeth have their bases folded, somewhat after the pattern of the fossil Labyrinthodonts. Professor Cope includes both the genera *Amia* and *Lepidosteus* with the Teleostean fishes.

ORDER III.—HOLOCEPHALA.*

FAMILY.—CHIMERIDE.

The Chimæra, which has sometimes been called the “King of the Herrings,” is like Sharks in having the nose projecting in front of the mouth, and resembles some Skates in the long tail, which tapers like a whip. But it differs in wanting the openings for the gills which are visible in both those groups; not that they are absent in the Chimæra, but are concealed by a backward fold of membrane like a rudimentary operculum, which extends in front of the pectoral fin. Under this membrane, which gives a single external opening for the gills on each side, are four clefts in the gill-cavity. There is another very important difference from the Sharks, in that the skull is blended with the jaws. The skeleton is almost entirely formed of cartilage, and almost the only bones in the body are those which form the jaws. The genus has hence been placed, together with an allied genus, as a separate division of the cartilaginous fishes (*Holocephala*). Very little is known of the habits of the *Chimæra monstrosa*, for it comes to the surface only in the night, and is rare in northern latitudes. It is often met with in the Polar Seas. Its ordinary food consists of Crabs and Shell-fish, but it also travels in pursuit of Herrings and other migratory fishes. It is also said to feed on Jelly-fish. The flesh is reported to be hard and coarse-eating. Oil has sometimes been obtained in Norway from its liver, and used for disorders of the eyes. The genus is represented by three species, but the common Chimæra ranges round the shores of Europe, and is not unfrequently caught on the Mediterranean coasts of France; and it is met with at the Cape of Good Hope and in Japanese waters. This species is hardly more than three feet long; the

* ὅλος, entire, solid; κεφαλή, head.



CHIMÆRA COLLIER.

colour is brown with marble-like markings of a lighter shade, often silvery-white. Behind the head rises the first dorsal fin, hardly separated from the second dorsal which extends all down the body. These fins have sometimes been compared in appearance to a mane. The large pectoral fins are remarkable for having their central portions fleshy, as in the Australian *Ceratodus*. The eggs are contained in very large leathery cases, the edges of which are like velvet. The male fish is distinguished by having jointed claspers, which are armed with small spines, and carries a very remarkable crest on the front of the head. The teeth are altogether unlike those of other fishes, since they consist of minute denticles firmly massed together into large tabular plates, which are inseparably blended with the jaws. The jaw-bones are well ossified, and have no trace of the cellular texture so characteristic of the bones of Plagiostomatous fishes about to be described.

The *Chimæra collei* is known from the west coast of North America, and the *Chimæra affinis* from the coast of Portugal.

The second Chimæroid genus—*Callorhynchus*—is found only at the Cape of Good Hope and in the Southern Pacific. The only known species is named *antarcticus*. It is distinguished from *Chimæra* by having a remarkable cartilaginous prominence upon the snout, which terminates in a flap of skin. There is the same long and strong spine in front of the first dorsal fin. The extremity of the tail, which has an upward turn, has a fin along its lower edge, while the *Chimæra* has a low fin both above and below the tail. The anal fin is better developed than in the *Chimæra*. The pectoral fins are remarkable for their large size. The young have a double series of small dermal spines on the crown of the head and on the back of the body and tail; but as the animal grows older they become more or less hidden by the skin, or otherwise disappear. The upper part of the body in the young is always black, with more or less of white markings and spots, but in the adult there is a blackish lateral band. The claspers are almost cylindrical, and have a channel running down the interior, which opens by a lateral slit. In the true *Chimæras* the clasper of the male is usually divided into two branches, which differ in form in the different species, and the inner branch is again subdivided into two, so that the clasper is tripartite.

ORDER IV.—PLAGIOSTOMATA, OR FISHES WITH OBLIQUE MOUTHS.*

Sharks and Rays form one of the natural divisions or orders of fishes which is named the Plagiostomata. The skin is rarely covered by overlapping scales; if it is covered at all with defences, they usually take the form of a rounded boss, from which a little spine, resembling a tooth, rises. This covering constitutes the shagreen of Sharks, and the scales were termed by Agassiz "placoid." Besides these, the body sometimes carries bony defences, which are usually placed in front of the fin, sometimes on the back, or occasionally on the tail. The vertebrae of Sharks usually consist of two thin cones, which join each other point to point, and are connected together by bony plates, which radiate from the centre to the circumference of the inter-space between the cones, and are at right angles to their surfaces. In the Rays the vertebrae are united in the fore part of the body into a continuous bony mass, resembling the sacrum in the hinder part of the body of mammals and birds. Among some Sharks the slender arches over the bodies of the vertebrae are sometimes twice as many as the centra. Many of these fishes have the end of the tail bent upward, and the fin is entirely below this bent portion.

These fishes are termed Heterocercal, but some Sharks have the tail more nearly symmetrical, and approach the Homocercal type of bony fishes. In the Plagiostomata the brain-case is formed

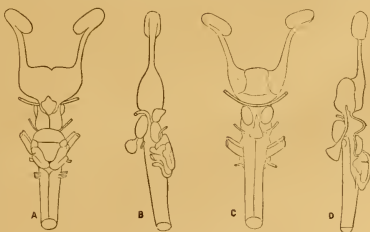


DIAGRAM OF BRAIN OF SKATE.

A, Upper View; B, Side; C, Under; D, Section.

* πλάγιος, slanting, στόμα, mouth.

entirely of cartilage, and terminates backward in two oblong processes called the occipital condyles, by which it joins on to the backbone or vertebral column. In this character there is a resemblance to the amphibia and to mammals; but the cartilaginous skull is covered with a thin layer of bone, which is deposited in cells like a minute tessellated pavement or honey-comb. There are large open spaces covered with membrane in the upper part of the skull. The upper jaw is not subdivided into separate bones any more than the skull; and the lower jaw also, unlike that of all other fishes, and like that of mammals, consists of a single piece of bone on each side. As there is never any cover to the gills, the opercular bones are also wanting. There are two pairs of lateral fins, which correspond to fore and hind limbs. The teeth vary in character. In the Sharks they are commonly sharp and pointed, and adapted for seizing and biting, but in the Rays they are more frequently blunt, and adapted for crushing. They are replaced when worn. These fishes never have an air-bladder; the intestine is always short, and terminates in a spiral valve. The part of the heart termed the aortic bulb is remarkable for containing three sets of valves for controlling the circulation. A great many Sharks and Rays have a tube leading from the mouth to the upper side of the head, which is called a spiracle. In the Sharks the gills open by five or seven vertical slits on the sides of the head. In the Rays there are always five pairs of gill-openings, which are placed on the under side of the body. The Saw-fishes connect these two groups. The brain is chiefly remarkable for the large size of the cerebellum, and the great development of the olfactory lobes. Usually there are two ovaries; but in certain Sharks there is but one. The eggs are large and few, but are laid only by Dog-fishes and Rays. The great majority of Sharks bring forth their young alive, and the young are sometimes attached to the body of the parent. The claspers of the males are often large organs.

SUB-ORDER I.—SELACHOIDEI, OR SHARKS.

The Sharks all have a more or less cylindrical body, which tapers to the snout and contracts gradually into a tail. The group has been divided into nine families, though the characters by which they are distinguished depend chiefly upon external characteristics. The families are named from typical genera *Carchariidae*, *Lamnidae*, *Rhinodontidae*, *Notidanidae*, *Scylliidae*, *Cestraciontidae*, *Spinacidae*, *Rhinidae*, and *Pristiophoridae*.

FAMILY I.—THE CARCHARIIDÆ.

These fishes form a large family distinguished by having an anal fin and two dorsal fins and a nictitating membrane, or third eyelid, like that of birds. The family includes eleven genera. The first dorsal fin is always placed opposite the space between the pectoral and ventral fins, and never carries a spine on its anterior margin. Dr. Günther has divided the family into several sections, some of which may be regarded as themselves forming families. In the genus *Carcharias*, in which there is always a pit at the root of the tail, and never any spiracles, the teeth, which are more or less triangular, have a single sharp cusp; they extend round a crescent-shaped mouth. In one section of the genus the teeth are more or less denticulated, but in the other section the teeth show no trace of serrations on their cutting margins. In *Carcharias*, Dr. Günther recognises thirty-five species, which have been classed by the characters of their teeth into as many as five sub-genera. The majority of these fishes are known from tropical seas. Their snouts are sometimes greatly elongated, but frequently blunt. The number of teeth varies in the different species, and is not always quite the same in both jaws, but usually ranges between twenty-five and forty-nine; the difference is rarely more than two in the upper and lower jaw, and frequently there is only a difference of one. Occasionally the excess is in the upper jaw, but more frequently in the lower jaw. The Blue Shark of English shores belongs to the section with serrated teeth.

THE BLUE SHARK.*

Towards Midsummer the fishermen on the Cornish coasts often find their nets and lines attacked by the Blue Shark. It follows the Pilchards and Herrings, and frequently bites out the part of the net in which the fish are entangled. When the bait on a line has been swallowed, and the fish has failed to bite the line through, it often rolls the rope round its body until it reaches the surface, coming up in

* *Carcharias glaucus*.

this way from a depth of thirty or forty fathoms. Its appetite shows a varied taste; the stomach of one fish six feet long was found to contain a large Piked Dog-fish, a Conger Eel, and a Grey Gurnard. Another was hungry enough to take the bait, though its stomach contained four Mackerel, half a Garfish, and a quantity of Herrings, which the fishermen, finding uninjured, afterwards sold for eighteen-pence. On one occasion a Blue Shark leaped a considerable distance out of the water to seize a piece of beef hanging on the quarter of a ship, and it is well known to attack man; but as it rarely enters harbours or approaches close to the land, its human victims are few. Fishermen assert that its sense of smell is offended by nauseous odours, so that it may be driven away by pouring bilge-water into the sea where it shows itself. The muscular vitality of these fishes is as remarkable as that of Reptiles and Amphibians, for in one recorded instance, after a Shark had been caught, and the body severed from the head and thrown overboard, it continued swimming about for hours. The power of the Shark's tail often makes the fish an inconvenient neighbour when drawn on deck, but when the tail is chopped off this danger is removed. It is, however, usual to disable the animal by a blow on the snout. It is occasionally accompanied by its young, which in June are about eighteen inches or two feet long. It remains in British seas for a time, straying as far north as the Orkneys, throughout the summer, and disappearing in the autumn. Hundreds are captured in a season by British fishermen; but the body is used only for manure, and oil is made from the liver. The largest examples reach a length of fourteen feet, but the usual size is six or eight feet. It is distributed throughout temperate and tropical seas, and has been recorded from Pondicherry, St. Helena, and the Mediterranean, but neither the limit nor direction of its migrations is at present known. The animal derives its name from the colour of the fins and the upper parts of the body, though the belly remains white. The mouth is placed far behind the projecting nose, and armed with triangular teeth which have their margins serrated like saws. The skin is rather rough, and the pectoral fins are large. The other fins are all small. All the fishes of this genus have the first dorsal fin placed over the space between the pectoral and ventral fins, and there never is a spine in front of this fin. The gill-openings are small, five in number, and are placed just in front of and above the pectoral fin. The majority of fishes allied to the Blue Shark are from the neighbourhood of the Malay Archipelago and Indian seas, but two or three species out of the thirty-five which are known frequent the West Indies and Tropical America.

There are many genera allied to *Carcharias* which have no representatives in the British seas. Among these are the *Hemigaleus*, from Java and Amboyna; *Loxodon*, from the Indian Ocean; *Galeocerdo*, which is represented in the Arctic seas by a species ten feet and a half long, while smaller species are found in the Atlantic and Indian Oceans and Australian seas. *Thalassorhinus* is found in the Mediterranean and the Atlantic. These four genera are all characterised by having spiracles, which distinguish them from *Carcharias*. They differ from each other in the characters of the teeth, lips, and tail.

The next genus, *Galeus*, differs from all the foregoing in wanting the pit at the root of the tail. Only two species are known, one from Japan, and the other (*Galeus canis*) is the common British Tope, widely distributed throughout all temperate and tropical seas, and ranging to the Pacific and Antarctic Oceans. It is common on the English south coasts in summer, and reaches a length of about six feet, but is usually smaller. The young are brought forth in summer. The number produced at a time varies. Couch records twenty-one at a birth, and sometimes thirty-two, but says that fifty-two have been known. The young when born are about a foot in length; they do not attain their full size until the second year, and remain near the coast through the first winter, though, as their size increases, they retire into deep water and swim low. When hooked, this species often, like the Blue Shark, twists the whole length of the line round its body. In France and Italy the Tope is used for food, being eaten fresh; but more frequently the flesh is dried, and afterwards soaked and grilled or stewed, but the only use made of it in England is melting the liver for oil. The young are commonly known to fishermen as the Miller's Dog, and the larger specimens as the Penny Dog. The young have the snout much shorter than that of the adult. The colour is a dark ash-grey above and white below. The teeth are serrated on the outer border, from which the smooth cusp projects outwards, but the broad front teeth are serrated on both sides. The gill-openings are five, placed in front of the pectoral fin, and are very short. There are one hundred and forty vertebrae.

THE HAMMER-HEADED SHARK.*

The Hammer-headed Shark differs from all others in having the sides of the head prolonged outward in the form of a capital T. The eyes are placed at the extremities of these remarkable transverse processes, and furnished with eyelids. The iris is of a bright golden yellow, with a black pupil. The mouth is relatively small, has the semicircular form usual among Sharks, is placed on the under side of the transverse expansion, and carries three, four, or five rows of triangular teeth, the rows becoming more numerous with age. The cutting-edges of the teeth in this Shark are smooth in the young, but



HAMMER-HEADED SHARK.

become serrated later in life. The teeth have no barbs at the sides. The nostrils open in front of the head, and are elongated. There are five clefts for the gills, which are at the side of the body, and placed between the pectoral fins and the hammer-like expansion which carries the eyes. This fish has two dorsal fins; the anterior one is placed over the space between the pectoral and ventral fins, and the hinder one is over the anal fin. The upper lobe of the caudal fin is long. The specimens captured in British seas are brown on

the back and paler on the under side, ten feet long, and measuring six feet in circumference. They are said to weigh between six and seven hundred pounds. The body of a female contained thirty-nine young ones, perfectly formed, each about nineteen inches long. The species frequents deep water, and is said to be ferocious. It has been taken on the Cornish coast, at Tenby, and on the coast of Norfolk. But its home appears to be in tropical and sub-tropical waters, since it is often met with in the Mediterranean, round the shores of the Indian Ocean, in the seas between China and Japan, and ranging southward through the Malay Archipelago as far as South Australia. There are in all five species known of this remarkable genus; and the other species occur in the Red Sea, on the coasts of India, in the Gulf of Mexico, and tropical parts of the Atlantic, but they all appear to have a wide range, and the Atlantic species has been met with in the Indian and Chinese Seas. Dr. Günther regards this genus as forming a second group of the Carchariidae, which he names Zygenina.

The third group in the family is Mustelina, from its type Mustelus. It comprises the genera Trienodon, from the Indian Ocean; Leptocarcharias, from South Africa; Triakis, from the Pacific and Indian Oceans; and Mustelus, which is represented by five species widely distributed in temperate and tropical seas.

THE SMOOTH HOUND.†

The only British species of Mustelus ranges round the European coasts, and probably extends as far as the United States. The name Smooth Hound refers to the circumstance that the skin is softer than the skins of other British Sharks. It grows to a length of about three feet, but is

* *Zygenia nalis*.† *Mustelus vulgaris*.

usually taken smaller. It is said to be sometimes used for food in the Hebrides. The mouth is below the eyes, and the teeth are flat like a pavement, and form crushing surfaces adapted to masticate the crustacea upon which these fishes usually feed. It is not very prolific, producing about a dozen young simultaneously in the month of November. The embryo is not attached in this species to the body of the parent. The caudal fin is short, and its hinder margin is usually whitish; the colour of the body is a uniform grey, with small whitish spots above the lateral line. These spots



SMOOTH HOUND.

are most marked in young specimens. In this genus the second dorsal fin is not much smaller than the first. There is always a nictitating membrane; there are small spiracles behind the eyes; and there is no pit at the root of the tail.

FAMILY II.—THE LAMNIDÆ.

The second family of Sharks (*Lamnide*) has no nictitating membrane, and no spiracles, or only minute foramina to represent them. The gill-openings are usually wide. Dr. Günther divides the family into two sections: first, the *Lamnina*, which includes *Lamna*, *Carcharodon*, *Odontaspis*, and *Alopias*; and secondly *Selachina*, which includes the genus *Selache*, and possibly the Portuguese genus *Pseudotriacis*.

The best known of the three species of *Lamna* is the Porbeagle Shark, sometimes called the Beaumaris Shark (*Lamna cornubica*), which occurs on British coasts, in the Mediterranean and

Atlantic, and has been taken in the Japanese seas. It is sometimes captured in mackerel nets and salmon nets, and has been taken on lines set for haddock. Cuttle-fish, cartilaginous fishes, hake, pilchards, and herrings, form its usual food. It appears to grow rapidly in early life, since it is nearly full grown before the second row of teeth is cut. Large specimens weigh fully eight hundred pounds, but the usual size is a length of four feet, with a body measuring two feet round in front of the pectoral fins. It is eaten in the Mediterranean, and used as manure in England. In the backbone there are 155 vertebrae.

In the genus *Lamna* the teeth are lanceolate, but there are not always little cusps at the base, though they are characteristic of the Porbeagle Shark. In that species the third tooth of the upper jaw on each side is remarkably small, and the width of the first gill-opening is equal from its distance to the last. There are specimens in the British Museum eight feet long.

The genus *Carcharodon* is known only from a single species which ranges from the Mediterranean to Australia. It has large, flat, regularly triangular teeth, with serrated margins, twelve on each side in the upper jaw and eleven on each side in the lower jaw. Fossil species have teeth which are sometimes nearly eight inches long. The second dorsal fin is placed in front of the anal fin. There are jaws in the British Museum obtained from Australian specimens which Dr. Günther states to have been thirty-six feet and a half long, and he appropriately quotes this species as the Great Blue Shark.

THE THRESHER, OR FOX SHARK.*

This species has acquired the name of Fox Shark from the enormous length of the upper lobe of its tail. The pectoral fins are very large, and the first dorsal fin is large. The teeth are triangular, and are not serrated. It is the only species of its genus, and is chiefly found in the Mediterranean and Atlantic. Specimens caught on the British coast have measured about eleven or twelve feet in length, one-half of which is formed by the tail. The snout is conical. Couch records that a splash of the tail of the Thresher puts a herd of Dolphins to instant flight; and instances are recorded of the Sword-fish and Thresher combining to attack large Whales. The stomachs of Threshers have generally been found filled with Herrings. It is rarely taken with the line, but is sometimes caught on the west and southern coasts of England in drift nets. The flavour of its flesh has been compared to that of the Salmon.

THE BASKING SHARK.†

The Basking Shark is one of the largest fishes of the group to which it belongs. It is sometimes as much as thirty-six feet in length. The circumference is enormous in proportion to the length. One which had a length of thirty-three feet measured twenty-four feet round. Its weight may be as much as eight or ten tons, and the height of its body above the ground may be eight or nine feet. This fish has the remarkable habit of floating on the surface of the sea and basking in the sun. It is generally seen between June and the beginning of winter; it abounds on the coast of Donegal, and frequents the west coast of Scotland when the wind is northerly. Westerly winds appear to bring it up the English Channel, and during their prevalence it has been seen, or cast ashore along the southern coast of England. These Sharks frequently swim in pairs, following each other, and the long moving mass has more than once been described as a Sea-serpent. On one occasion the Sea-serpent was supposed to have been cast ashore on the Sussex coast; when examined it was already in an advanced state of decomposition, but was measured by the village schoolmaster, and sketched, and considered to have a length of about seventy feet. Fortunately a few joints of its back-bone were collected, and afterwards examined. They presented all the characters of the vertebrae of the Basking Shark; and two large individuals lying end to end satisfactorily accounted for the supposed length of that Sea-serpent. The teeth of this Shark, in proportion to its size, are smaller than in any other member of the group, rarely attaining the length of an inch. The gape of the mouth may amount to as much as three feet. These Sharks are remarkable for the large size of the liver, which yields an immense quantity of oil. Couch, quoting from Brabazon's account of the fisheries of Ireland, says that large shoals of these Sharks pass annually in April and May to the north along the west coast of Ireland, where they are known as the Sun-fish, and are seen from a distance, about a hundred miles west of Clew Bay, lying motionless on the surface of the water, out of which the large dorsal fin rises like a

* *Alopias vulpes*.

† *Setula maxima*.

sail three or four feet high. They are easily approached and struck with a harpoon, when the fish at once darts away, and carries out from seventy to two hundred fathoms of line. Reaching the bottom he rolls himself, and rubs his wound against the ground to get free from the harpoon. After about an hour the fishermen begin to haul upon the harpoon line, which is coiled up in preparation for the fish making another rush. In this way he is often played with for eight or nine hours before he can be got to the surface. When this happens two or three more harpoons are fixed in him, and he is drawn alongside the vessel, stretched fore and aft. A jowl rope is got round his head, and a hawser round his tail. The tail is then cut deep on each side with a hatchet, and the fish in its agony lashes so furiously that the tail becomes broken. Large flesh holes are then cut in the body on both sides, and through these ropes are passed; then by hauling on one side and slacking the rope on the other the fish is canted over on his back. The fishermen then split down the stomach and take out the liver, which is said to weigh about two tons, and to make from six to eight barrels of oil. The rest of the fish is cut adrift, for the fishermen have a superstition that if the bodies were brought on shore the Sharks would abandon the coast. They require to be harpooned with great caution, low down on the side of the dorsal fin, so that the weapon may go through the intestines; or they are sometimes struck near the tail vertebrae; but this operation requires care, as a blow from the tail would stove in the boat. As many as five hundred of these Sharks have been killed in a single season. Their value ranges from £35 to £50 each. Oftentimes a hundred of them together may be seen towards the end of June basking in the sun on the north-west coast of Donegal. In the Orkneys they appear to be rarer. The liver of one twenty-seven feet and a half long captured near Whalsay in November yielded 165 gallons of oil, and was sold for £16 10s. That shark was caught by the herring-fishermen with a six-oared boat. It appears to have taken a mouthful of herrings, and then to have rolled the net with the ropes five times round its body. Two Scottish specimens thirty feet long, caught at Broadhaven, yielded nineteen barrels of oil, eight of which go to the ton.

The body is thickest in the middle, is nearly cylindrical, and tapers to the two ends. The skin is rough with the shagreen covering, and dark-brown in colour. The head has a conical form, with a short muzzle, covered with a number of circular pores. The eyes are small and near the snout. The iris is brown. There are five branchial clefts in front of the pectoral fins which are remarkable for their enormous depth, so that they go far to encircle the anterior part of the body. The nostrils are small, and placed laterally on the edges of the upper lip. The second dorsal fin is much smaller than the first. From the anal fin to the base of the tail the body has a prominent keel on each side. The caudal fin has a large upper lobe and a small lower lobe, but its form varies with age and the rough usage to which it is subjected. Its food is said by Linnaeus to consist of Medusae, but there are no satisfactory records of animals found in its stomach. A fine specimen cast ashore at Shanklin is preserved in the British Museum. It is a species which especially frequents high northern latitudes.

FAMILY III.—RHINODONTIDÆ.

This family is known only from the *Rhinodon typicus*, caught between the Cape of Good Hope and the Seychelles. Like the Basking Shark, it has a keel on the tail, and the teeth are extremely small, numerous, and conical, and the mouth is placed near to the extremity of the snout.

FAMILY IV.—NOTIDANIDÆ.

This family is also known only from a single genus, *Notidanus*, in one species of which there are six gill-openings, forming the section *Hexanchus*, while in the other three species the gill-openings are seven, forming the section of the genus named *Heptanchus*.

THE SIX-GILLED SHARK.*

The Grey Shark is sometimes eleven or twelve feet long. It possesses but one dorsal fin, which is placed just over the anal fin, and is not supported by a bony spine. The snout is rounded, thick, and blunt. The eyes are large, slightly oval, and placed just above the corners of the gape of the jaw. There is no eyelid to defend the eye. The teeth form a single row in each jaw. In the lower jaw the crowns are oblique and serrated. They are six in number on each side. In the upper jaw there are six teeth on each side; their points are slender and sharp, without serrations,

* *Notidanus griseus*.

and are directed towards the angles of the mouth. In front, in the middle line, are four more awl-shaped teeth. The six openings for the gills are placed very close together, and extend under the throat so as almost to encircle its lower part. The scales are very short and leaf-shaped, with a median keel which runs to the sharp point. Specimens taken off Ventnor have measured eleven or twelve feet in length. The pectoral fins are unusually wide and triangular. The caudal fin is about a quarter of the length of the fish, and more slender than in any other British Shark except the Thresher. The hinder two-thirds of the upper margin of the tail are armed with three parallel rows of spines, the lateral rows diverging outward. Though known as the Grey Shark, the back and fins have a blackish-brown colour, but it is white underneath, and of a warm grey tint at the sides. It has several times been taken with a line on the South coast of Britain. Large specimens are said to have many rows of teeth in the lower jaw. It is often met with in the Mediterranean, and frequents the Atlantic. The three other Sharks closely allied to this, which have been placed in the section *Heptanchus*, are *Notidonus platycephalus*, distinguished by its short blunt snout, which is found only in the Mediterranean; and the *Notidonus cinereus*, found in the Mediterranean and adjacent coasts of the Atlantic, which has the snout prolonged and pointed. The third seven-gilled Shark, called *Notidonus indicus*, ranges from the Cape of Good Hope to California.

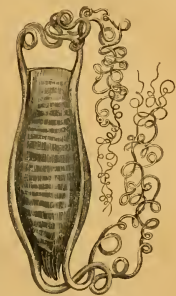
FAMILY V.—THE SCYLLIIDÆ, OR DOG-FISHES.

The term "Dog-fish," as might be expected, is used vaguely by fishermen for a number of distinct Sharks. Along the English coasts there are several nearly-allied forms known as the Spotted Dog-fish, or Nurse Hound, and the Black-mouthed Dog. The Nurse Hound, or larger Spotted Dog (*Scyllium stellare*), and the smaller species known as the Rough Hound, or lesser Spotted Dog (*Scyllium canicula*), usually live at the bottom of the sea, and in rough and rocky places. They feed for

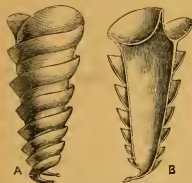


NURSE HOUND.

the most part on Crabs and Lobsters, though they readily take any tempting food that comes in their way. They rarely come near into shore, and are caught in summer and autumn. The eggs of these fishes are contained in oblong purse-like cases, as tough as leather, with long tendrils at the four corners, which coil up and hold the egg to some coralline, or gorgonia, or sea-weed. The eggs are deposited one or two at a time. The Nurse Hound deposits them late in the year, but the Rough Hound lays its eggs throughout summer and autumn. Its purses are of a pale yellow colour, with tendrils which may be stretched out to a length of two feet. The eggs have been found unhatched as late as the middle of December. There are four slits at the corners of the egg-case, but their function has not been discovered. The flesh of the Nurse Hound is too rank to be eaten, but in the west of Cornwall the Rough Hound is made into Sea-dog soup, called from its ancient British name "Morphi," but in the Mediterranean the Rough Hound appears to be an ordinary item of food. Sharks are of rapid growth, and reach their full size in a few years, but there are no means of judging what age they attain. The Nurse Hound grows to a length of four or five feet. Its colour is dusky-red, with many large dark spots on the body and fins. The skin is rough with minute spines, which are directed backwards. The body is elongated posteriorly; the pectoral fins are placed low down at the sides of the head, and are wide. There are five small branchial clefts placed close together in front of the pectoral fin. The mouth is very close to the end of the snout, and when opened is circular. The Black-mouthed Dog-fish, which forms the genus *Pristiurus*, differs in having a long snout with the mouth placed below the large eye. It is well known in Italy, where it has received from the Italian fishermen the name "Bocca d'Inferno," or "Mouth of Hell." The eggs are deposited in cases which have, according to Yarrell, the tendrils at one end only, and too short to be capable of twining round any fixed substance. The purses are about an inch and a half long, of a tawny yellow-brown colour, with a smooth shining surface. The body is spotted, but the spots are oblong and arranged in two rows. The colour of the upper part is made up of many tints of brown and yellow, while the belly is pale. The dorsal fins are placed far back, the first dorsal beginning behind the ventral fins. These fishes are a little over two feet long.



EGG PURSE OF NURSE HOUND.

EGG OF *CESTRACION* (A); SECTION OF THE SAME (B).

The Dog-fishes are widely distributed, some of the species ranging over the Indian Ocean, others from Japan to Amboyna; one is recorded from Tasmania, another from Chili, and one or two from the Cape. There are in this family five other genera, which have much the same distribution as the genus *Scyllium*.

FAMILY VI.—CESTRACIONTIDÆ.

This family is known only from the genus *Cestracion*, of which there are four species. Here, for the first time, spines are met with in front of both the dorsal fins; the nostrils unite with the cavity of the mouth, which is narrow, and has the upper lip divided into seven lobes. The teeth in both jaws are similar; they change their character as the animal grows older. In the

middle there are small teeth, which at first have from three to five cusps, but afterwards become small and blunt. External to these are large lateral teeth, twice as broad as long, which are arranged in oblique series so as to form a sort of tessellated crushing surface. The best known species is the Port Jackson Shark (*Cestracion philippi*), which ranges from Japan to New Zealand. The backbone contains a hundred and ten vertebrae, only fourteen of which intervene between the skull and the first dorsal spine. The body is marked with more or less distinct dark bands, which give the fish a Zebra-like appearance. There is a second Australian species, one from the Galapagos Islands, and another

from California. Both the latter are distinguished by having round black spots over the body and fins. All the species are small.

FAMILY VII.—SPINACIDÆ.

This family includes ten genera. The genus *Centrima* is found in the Mediterranean, on the coasts of Portugal. *Acanthias*, known from three species, like all the other members of the family, wants the anal fin. The British representative is called

THE PICKED DOG-FISH.*

The Picked Dog-fish is the smallest and most abundant of British Sharks. It is most plentiful on the west and south coasts, and Couch records that the sea is often covered with it for scores of miles, and



PICKED DOG-FISH.

that twenty thousand have been taken in a seine net at one time without visibly lessening their numbers. It is a remarkably hardy fish, and never seems to suffer either from the severity of winter cold or summer heat. The name is derived from the spines placed in front of each of its two dorsal fins. On the coast of Kent and Sussex it is usually known as the Bone-dog; in Orkney it is the Hoe; in Cornwall the male is known as the Skittle-dog. The spines are used as offensive weapons, and are directed with marvellous accuracy against the object to be pierced. For nine or ten months in the year the female produces young almost every day. The young are extruded in pairs, and develop rapidly. Yarrell records that these Sharks have occasionally been found in a monstrous form, there being two heads, with the separation continuing backward to behind the pectoral fins; but there is no evidence that such monsters attain to maturity. The young ones accompany their parents in pursuit of prey, though their jaws are too feeble to capture or even attack the fishes on which their parents feed. Frequently this fish bites jagged holes in the net, and cuts the hooks from the fishermen's lines. It has

* *Acanthias vulgaris*.

been found in the stomach of the Blue Shark, the Ling, and other fishes. It is eaten, both fresh and salted, by the fishermen of the West of England, and Lacépède records that in the North of Europe the eggs, which consist of pale-coloured yolk, and have the size of a small orange, are highly valued as an article of food. The usual length of the fish is between eighteen inches and two feet. The female is larger than the male, and old specimens have been found which weighed twelve pounds. The top of the head is flat. The first dorsal fin, which is rather small, is placed a third of the length of the animal from the snout; the second dorsal fin is midway between the first and the end of the tail. The upper part of the body is of a slaty-grey, and the under parts are yellowish-white. From head to tail the skin is smooth, but in the opposite direction rather rough. The species ranges throughout the European seas, and is taken in the western part of the Mediterranean, at the Cape of Good Hope, and on the coasts of Australia. The dorsal spines are distinguished by having no longitudinal groove on the sides, a feature which is also characteristic of the Mediterranean species *Acanthias uyatus*.

The genus *Centrophorus* is represented by eight species. In one of these (*Centrophorus cololepis*), from the coasts of Portugal and Madeira, the dorsal spines are hidden beneath the skin. All the species are covered with scales, and in three there are from four to six keels on each scale; in two there is only a single median keel. Another species has three strong ribs on each scale, each rib terminating in a point, and in all these species the spines of the dorsal fins project beyond the skin. The species are all small, rarely exceeding a length of three feet, and the colour is generally brownish-black.

The genus *Spinax* occurs in the European seas, and one species (*Spinax pusillus*) ranges across the Atlantic from Cuba to Madeira. Both species are of brown or black colour, and reach a length of twelve or fourteen inches.

The genus *Centroscyllium* is known only from a single species from Greenland, about two feet six inches in length.

Scymnus lichia is from the Mediterranean and Atlantic.

Læmargus has one representative in the Mediterranean and another (*Læmargus borealis*) in the Arctic seas, where it attains a length of twenty-five feet. Smaller specimens of this species from time to time visit British shores. According to Scoresby, it is an enemy of the Great Greenland Whale. It often bites pieces out of the flesh of the living animal, but when the Whale is dead it gorges itself upon the blubber, and refuses to be driven away, even though pierced through with a spear. It will also feed on small fishes and crabs. When fresh it is brown, deeply shaded with blue. The rows of teeth vary with age, from two to six. The simple cusps in all the rows diverge laterally from the centre.

The genus *Euprotomierus* is known from a small species found in the Indian Ocean.

Echinorhinus also has but one species, which is known as

THE SPINOUS SHARK.*

The Spinous Shark ranges in the Atlantic from the shores of Britain to the Cape of Good Hope, and sometimes enters the Mediterranean. It is of an awkward shape, and is remarkable for small fins and small tail. It would appear to feed chiefly upon crustacea. The liver of a specimen five feet and a half long yielded a gallon of oil, but specimens have been taken between eight and nine feet long. The body is covered with sharp spines, which are absent from the snout and fins and from the belly. The dorsal fins are close together, and both near the tail. It has been taken in the trawl-net, and on lines baited with Cuttle-fish. The fins have a reddish-brown colour; the eyes are green; the sides and belly are reddish-yellow, with vermilion blotches. The gape of the jaw is wide, and the teeth are large, compressed, and have the cutting surface horizontal, usually with two cusps on each side. The bases of the spines on the body are circular, and the spines are slightly recurved. The lateral line is well marked; it originates above the five openings for the gills, and extends backwards to the commencement of the caudal fin, which it then ascends to its upper extremity.

FAMILY VIII.—RHINIDÆ.

This family contains only the Monk-fish, or Angel Shark.

* *Echinorhinus spinosus*.

THE MONK-FISH.*

The Monk-fish, or Angel Shark, has a form and appearance intermediate between the Sharks and Rays. This is owing to its greatly-expanded pectoral and ventral fins, which more closely approach in plan to those of the Sharks, since the bones which form them consist of an expanded piece which has a narrow surface approximating towards the vertebrae, and gives off from its outer margin a number of rays, so as to present some resemblance to a palm-leaf. The body is



MONK FISH.

depressed, and tapers to the tail. The head, which is rounded, is separated from the pectoral fins by a short neck, and the nose is not at all developed in front of the mouth. The ventral fins are placed at the sides of the body just behind the pectoral fins, and the two small dorsal fins are between the ventral fins and the tail-fin. It generally remains near the bottom, and only rises in the water in pursuit of other fishes. It feeds chiefly on Flat-fish, and like them sometimes hides itself in the loose sand. The young are produced alive about July, when they are about a foot long. Its length appears usually to be from four to five feet, but occasionally reaches as much as seven or eight feet. The breadth of the pectoral fin is always more than half its length. The gill-openings, five in number, are rather wide, placed at the sides of the body towards the under surface, and partly covered by the pectoral fins. The skin is rough all over; a row of spines runs down

* *Rhina squatina*.

the middle of the back; there are half-circles of spines like eyebrows behind the eyes, which are placed on the top of the head, and are covered with skin, except round the pupils. Their colour is sandy-grey. There are about a hundred and twenty joints in the vertebral column; none of the vertebrae are united together, as among Rays. The arches over the spinal cord are broad plates, which cover the bodies of two vertebrae. The teeth are arranged at intervals, with four or five successional teeth behind the outermost one. This Shark was well known to the Greeks, who used its skin in polishing wood and ivory. Its flesh was also valued for food, and is described as firm and nourishing. It is still eaten in the north of France.

The males of this species, like most other Sharks, are furnished with prehensile appendages termed "claspers," but they do not here attain a large size. The species is widely distributed in temperate and tropical seas, being found in the Atlantic and on both sides of the Pacific.

FAMILY IX.—PRISTIOPHORIDÆ.

This, the ninth and last of Dr. Günther's families of Sharks, also only includes one genus—*Pristiophorus*—characterised by having the cartilage of the fore-part of the head prolonged into a long flat plate, which is armed on each edge with a series of teeth, so as to resemble a saw. There are also numerous rows of teeth in the upper jaw, sometimes as many as fifty-eight. The nostrils are on the under side of the head. The scales are minute and keeled, and they more or less completely cover the dorsal and pectoral fins. The body is somewhat depressed; but the gill-openings are lateral, while in the other Saw-fishes of the next family they are on the under side of the body. The species range from Japan to Tasmania, and sometimes reach a length of five feet.

The abundance of Sharks on the coasts of India appears to depend upon the presence of the Oil Sardine (*Clupea scombrina*), so that in some years, when these fishes are rare, or scarcely visit the coasts, Sharks are also comparatively scarce. They have for many years been sought for for the sake of their livers, which are used for the manufacture of medicinal oil. The livers are equally good at any season of the year, but while small livers yield one-third of their weight of oil, the large ones yield one-half their weight of oil. The best have a pinkish colour, and are firm. Those used in the manufacture vary in weight from 40 lbs. to 290 lbs. The Sharks are captured with baits of putrid beef or porpoise flesh, which are put on the hook and attached to a chain. The fishing is carried on in deep water, between four o'clock in the morning and sunset. The process of manufacture of the oil is comparatively simple; the livers have to be received at the factory within six hours of the death of the fish; the veins are slit up and the gall-bladder removed, and the gland is washed until it no longer discolours the water. It is then cut up into pieces which weigh about 4 lbs. each, placed in an earthen vessel and covered with about an inch and a-half of water. The vessel is then heated over a slow fire for about a quarter of an hour, till it reaches a temperature of 130° Fahr. It is then stirred up, and as froth begins to rise the vessel is cooled on sand. The oil floats, and is skimmed off with a ladle formed from half a cocoa-nut shell attached to a bamboo handle. This rough oil is strained through flannel, and then allowed to stand for three or four days, when it is again strained through layers of long-cloth, satin-cloth, and flannel, and again stands for a fortnight or three weeks. The straining is then repeated. In all there are six strainings, the last being through cloth and filtering-paper direct into the bottles in which it is stored. This oil has a light straw colour, and closely resembles cod-liver oil. The cost of its manufacture, however, has of late increased so much that the Indian Government, which formerly carried on the industry at Calicut, has found it less expensive to import cod-liver oil from Europe.

SUB-ORDER II.—BATOIDEI (RAYS).

All the Rays have a depressed flattened body, which is expanded by the pectoral fins into a more or less rhomboid or ovate form, usually terminated by a slender tail. Many species have the snout pointed, though this character is by no means universal. The gills always open on the under side of the body, and are always five in number. They communicate with spiracles, which open on the head behind the eyes, and supply the gills with water while the animal lies on the ground. These spiracles can be closed voluntarily. It has been estimated by Monro that, owing to the numerous foldings of the gill-surface, the entire area of respiratory tissue is equal to the whole external surface

of the human body. The auditory apparatus is well developed in all the Rays, and the eyes are more complex than those of Sharks. They are always placed on the top of the head, are directed sideways, are placed at some distance from each other, and are defended by a cartilage above, behind which there is usually a row of spines. Below the cartilage is an eyelid, which is capable of covering the pupil. The pectoral fins have a general resemblance to those of the Monk-fish, or Angel Shark. As the rays which compose the fin extend outward, they subdivide and become jointed, and in the common Thornback number eighty-two, and have twenty joints between their origin and outward termination. The ventral fins almost form a continuation of the pectoral fins. The claspers of the male are long and strong, and have joints which allow them to be moved in almost any direction. They are placed just in front of the inner side of the ventral fins. Rays have no anal fin. There are usually two small dorsal fins. All the Skates lay eggs, which are contained in a case or purse, which closely resembles that of oviparous Sharks. In the embryo the tail is relatively longer than in the adult, but Couch remarks that by a process not unlike that which deprives the tadpole of its tail, the part of the body which lies behind the dorsal fins gradually ceases to be nourished, and diminishes in size.

The Rays form the second subdivision of the Plagiostomous fishes, and compose the section Batoidei. They have been subdivided into six families by Dr. Günther. Most of these fishes feed on small crabs and shell-fish, for the mastication of which their flat teeth are well suited.

FAMILY I.—THE PRISTIDÆ.

This family, like the Pristiophoridae, is distinguished by the same characteristic of an exceedingly long flattened snout, armed along each edge with a series of strong teeth, much like a rough saw, so that it closely resembles the last group of Sharks. The skeleton of the saw consists of three, four, or five hollow and somewhat cylindrical tubes, which taper towards the end, and are encrusted with a granular osseous layer, such as is usual in the bones of this group of animals. These tubes are the greatly elongated and enlarged cranial cartilages, which are prolonged forward in Sharks and Rays to form the ordinary rostrum or snout, though, as a rule, those cartilages vary in number from one to three. The teeth are implanted in sockets, and have square bases. It is needless to remark that these teeth of the Saw-fish have no relation to the ordinary dentary armature of the jaws, but rather correspond to the scales or tubercles of the skin, which are here implanted and developed so as to closely simulate teeth. There are five species of the genus *Pristis*. They agree in having the body depressed and elongated. The gill-openings are on the under side of the head, are moderately wide, and placed between the pectoral fins. The nostrils are also on the under side of the head; the teeth are minute and blunt. There are wide spiracles or blow-holes behind the eye, and the eye has no nictitating membrane. The pectoral fins have the front margin free, and are placed behind the head. The species are widely distributed in tropical seas. The dorsal fin is sometimes in advance of the ventral, as in *Pristis perotteti*, sometimes opposite the ventral, as in *Pristis pectinatus* and *Pristis antiquorum*, in both of which species the caudal fin has no lower lobe. *Pristis cuspidatus* has the dorsal fin entirely behind the ventral, and in this East Indian species the rostrum is toothless towards its base. The number of pairs of teeth in the saw varies in this species from twenty-five to thirty-four, the number apparently altering with age. In *Pristis antiquorum* the number of pairs of teeth varies from sixteen to twenty, and the teeth have the cutting edge in front only. The longest Saws in the British Museum have a length of five feet, and belong to this species, which is common in the Atlantic and Mediterranean; those of *Pristis zyseron*, from Amboyna and Ceylon, are equally long.

FAMILY II.—RHINOBATIDÆ.

This family includes three genera, which have the body moderately expanded, with the rayed portion of the pectoral fin stopping short of the snout. The tail is strong and elongated, and carries two well-developed dorsal fins; but the caudal fin sometimes wants the lower lobe. The family includes three genera. *Rhynchobatus* has the nostrils forming oblique wide slits on the under side of the head. The two species range from the Indian Ocean to the China Sea. In *Rhinobatus* the cranial cartilage is prolonged into a long rostrum; the space between the rostrum and the pectoral fin is occupied by membrane. The depressed body tapers

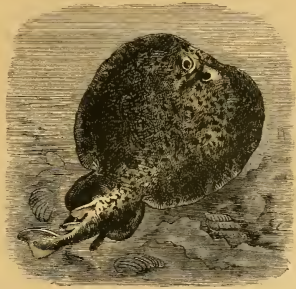
gradually to the tail. The teeth are small and obtuse, but each has a slight transverse ridge which is not seen in the previous genus. There are twelve species found in the warmer seas. The skin is usually coarsely granular, and covered with a series of tubercles, which often have large compressed spines in the median line. The mouth is commonly straight, but is occasionally arched, and is frequently longer than the nostril. Specimens of *Rhinobatus granulosus* from India, in the British Museum, have a length of seven feet, but jaws of a large example are fifteen inches wide. Most of the species appear to be smaller than this. Trygonorhina is an Australian genus, distinguished by the great width of the nasal valves.

FAMILY III.—TORPEDINIDÆ.

The Torpedo family includes six genera, which are all distinguished by possessing electric organs formed of hexagonal columns, which extend vertically, and are spread between the pectoral fins and the head. They all have the nasal valves confluent, with a quadrangular flap or lobe, as in Trygonorhina. The trunk is always a broad smooth disc.

THE GENUS TORPEDO.

The Torpedo has the body in front of the ventral fins more or less transversely ovate. The surface of the body is smooth, soft, and somewhat rounded. There are two small dorsal fins placed on the tail, which ends in a caudal fin having the lobes above and below nearly equal. Where the *Torpedo marmorata* occurs on the British coast it is familiarly known as the Cramp-fish, Numb-fish, and Electric Ray. When it is grasped by the hand a creeping sensation is felt in the whole limb up to the shoulder, accompanied by violent trembling and sharp pain in the elbow. As its vitality declines, the electric properties are lost, and are entirely wanting in the dead fish. The shock is sufficient to kill a duck, and in one of the early experiments made by Mr. Walsh, who placed a Torpedo on a wet napkin, the shock was felt by five persons, who received it from a wire extending from one end of the napkin into a basin of water, and transmitted it by putting a finger of each hand in similar basins. There are two electric organs placed on each side of the head and gills. They consist of many perpendicular prisms, which are mostly hexagonal and form large flattened organs having the shape of kidneys. Each column in the living fish appears like a mass of clear trembling jelly. These cells occupy the thickness of the body between the dorsal and ventral covering. Hunter counted 470 columns in each organ, and says that the partitions between them are full of arteries which bring the blood direct from the gills. These organs appear to convert nervous energy into electricity. The nerves which extend through them are an electric branch of the trigeminal or fifth nerve, and four nerves which are branches from the side of the medulla oblongata, or hindermost part of the brain, each as thick as the entire spinal cord itself. These nerve trunks subdivide and penetrate into the partitions between the columns. It has been taken on many parts of the British coasts, but more frequently in the English Channel than elsewhere. Specimens taken in Cornwall have sometimes weighed a hundred pounds, but usually they weigh only half as much. An example which weighed forty-five pounds was forty-one inches and a half long by twenty-nine inches and a half broad, but on the following day its dimensions had altered to forty-two inches by thirty, though it then weighed only forty-three pounds and a half. After death the plump appearance of its upper surface is lost, and the lower border curls upward. It is usually taken in the trawl, but sometimes with the line. The colour is a dark brown, which is lighter round the eyes. The specimens which occur in the Mediterranean are usually



TORPEDO MARMORATA.

spotted. The teeth carry little barbs, rising from an expanded base. The mouth is small, and the jaw-bones slender. The nostrils are closer to the sides of the mouth than is usual with the Rays. The eyes are small, deeply imbedded, and directed upward. The spiracles are small and oval, and placed directly behind the eyes. The intestine is remarkably short, being less than half the length of the stomach. All the animal's movements are slow, and it prefers soft and muddy ground. Pennant remarks that it is eaten on the coasts of France, but Galen believed that when used as food the person eating it became stupid and dull. In the Middle Ages it was often prescribed for the cure of headaches. This species is distributed throughout the Mediterranean, and is found all over the eastern part of the Atlantic and the Indian Ocean. There is a second British species (*Torpedo hebetans*), which also occurs in the Mediterranean and adjacent parts of the Atlantic. It has the ventral fin more rounded, and separated from the pectoral fin, and has the body of a dark chocolate-brown above, and white on the under side. There are four other known species of the genus *Torpedo*, which frequent the Red Sea, the east coast of Africa, and the Mediterranean. The five other genera of this family all frequent tropical and sub-tropical seas, and are widely distributed on both sides of America, and range as far north as Japan, and as far south as Australia.

The genus *Narcine* has the tail longer than the disc, and has the spiracles immediately behind the eyes. The teeth, which are almost flat, sometimes are marked with a median point. There are four species. In tropical America *Narcine brasiliensis* is met with penetrating into fresh waters.

The genus *Hypnos* has a remarkably short tail, body entirely naked, and tricuspid teeth with slender points. Only one species is known, which has minute eyes. The upper part of the body is black, and sometimes spotted with white. It is found only in the Australian seas.

Discopyge is another genus with the body entirely naked, but the tail is better developed and distinct from the circular disc. The teeth are flat. The ventral fins are united, and the vent is in the middle of the length of the body. Only one species is known from the coast of Peru.

Astrape has pointed teeth, and only one dorsal fin on the tail. There are two species of this genus.

Temera is a genus which differs from *Astrape* only in having entirely lost the dorsal fins, and in having blunt teeth.

FAMILY IV.—RAJIDÆ (THE RAYS).

The family of Rays is distinguished by having a broad rhombic disc formed by the pectoral fins extending to the snout. The skin is covered more or less with spines, which are short and sharp, and have a broad thick base. The electric organ is absent, and the tail never carries a bony spine. There are four different genera, which have these characters in common, but three of them are only known from single species, and are limited to the seas of India and China and the southern coasts of South America. In the genus *Raja* the tail is always well distinguished from the disc. The caudal fin is either absent or but very slightly developed. The teeth may be either blunt or pointed, but, like the dermal spines, differ in form with sex. The number of species in British seas has probably been over-estimated, and may not exceed eight, though most authors enumerate a dozen; and altogether about twenty-five species are known from various parts of the world. The True Skate of the British fishermen (*Raja batis*) is one of the most abundant fishes of the British coasts. It is found almost everywhere in the south, and has been taken as far north as the Orkneys. It ranges round the shores of the German Ocean, and attains a large size. A stuffed female in the British Museum is five feet and a half broad and six feet and a half long. A specimen weighing 200 pounds was on one occasion dressed by the cook of St. John's College, Cambridge, and found sufficient for 120 members of that society who sat down to table. When caught in the Mediterranean it is valued as a delicacy, and in Schleswig-Holstein it is salted and dried for the German market. The fishermen of the southern coast of England esteem it chiefly for bait, since when stale it is always successful with Lobsters and Crabs. When caught on the hook it is almost impossible to raise it, as the animal usually lies still and keeps its head down, but when once the head is raised the fish rises in the water like a kite in the air. In the breeding season Bloch declares that each female is followed by several males. The purse in which the eggs are contained has an oblong shape, and a length of four or five inches. The eggs are dropped in pairs, and left to take their chance of development, and if dropped near to shore they are often washed up on the beach in rough weather. They are most

easily taken when the hooks are baited with Pilchards or Herrings, though one kept in captivity by Sir John Dalyell would feed on nothing but Whiting. Couch records that in the stomach of one animal he found a Fishing Frog that weighed six pounds, in another two large Plaice, a Lobster, a couple of Mackerel, a Thornback Ray eighteen inches long, and half a Salmon. The colour of the upper part of the body is dusky grey or mottled, and its colour has caused it to be known in Scotland in some places as the Grey Skate, and in others as the Blue Skate. At Lyme Regis it is called the Tinker. The females are always called Maids. This species is frequently infested by the Fish Leech, *Hirudo muricata*.

THE LONG-NOSED SKATE.*

The Long-nosed Skate has the snout prolonged to a sharp point far in advance of the mouth. The anterior outlines of the body are concave. Its usual size, according to Couch, is four feet seven inches long, with a breadth of a little over three feet; the tail measures sixteen inches. The body is of a lead colour, greatly flattened and smooth. On the under side it has dark spots similar to those of the Common Skate. The skin is smooth, but the tail is rough and armed on each border with a row of large recurved spines, but is without any spines in the median line. The teeth are sharp, but closely packed together on a semicircular curved surface of the bone, and in the upper jaw form forty-six rows. In the young the teeth in both sexes are flat, but as the male acquires age his teeth towards the centre of the mouth become elevated, keeled, and pointed. The females are larger than the males. The eggs are deposited in the latter part of the spring or summer in the usual purse-like cases. In London Skates are generally brought to market in autumn and winter, since the flesh becomes soft and woolly during the breeding season. The species is caught in deep water, and is always violent on the hook, but a large number are taken in trawl-nets. It ranges all round the shores of the North of Europe.

THE BORDERED RAY.†

In this fine species the anterior outlines of the body are deeply undulated, and the snout contracts rapidly into a slender forward process. The posterior outlines of the body are relatively short, so as to give the disc a triangular appearance. The body is smooth above, but the tail has a median row of spines, and there are stronger lateral rows on each side. This species is very much thicker and heavier than the Common Skate, and is frequently eight feet long, and a little broader. The colour is grey above and white below. The claspers of the male are long and stout. The adult animal frequents deep water, and is taken only in summer and autumn. It is in great demand in France, and during Lent the French fishermen come to Plymouth and the south coast of England to purchase this species, which is covered with wet sand to keep it fresh during the run back to France. In Scotland it is known as the White Skate; in Cornwall as the Burton Skate. It has been taken as far south as Madeira, but is characteristic of the European coasts.

THE SHAGREEN RAY.‡

This Ray has a double series of strong spines on the upper surface of the tail, but none in the median line, except a short series in the middle of the back. There are spines arranged in semi-circles like eyelids between the eyes; the anterior borders of the body are undulating, much as in *Raja marginata*. In both sexes the teeth are slender and in the upper jaw are arranged in about sixty rows. The body is covered with minute spines both above and below, and these have secured for it the name of Shagreen Ray. It is a species of moderate size, being about two feet eight inches long, and one foot two inches broad; it is often taken in the North of England and Scotland, and is said to feed on small Star-fishes and various kinds of Crustacea, but has been taken on hooks baited with the Sand-eel. Its flesh is soft and dry, so that it is less sought after for food than some of the other species.

THE HOMELYN RAY.§

The Homelyn Ray is a smooth-skinned species which has the body of a sub-pentagonal form. There is a median series of spines running along the middle of the back and tail, and usually a lateral series also, along the tail, which are absent from the back. This species is very variable in its ornament,

* *Raja vomer*.

Raja marginata.

‡ *Raja fullonica*.

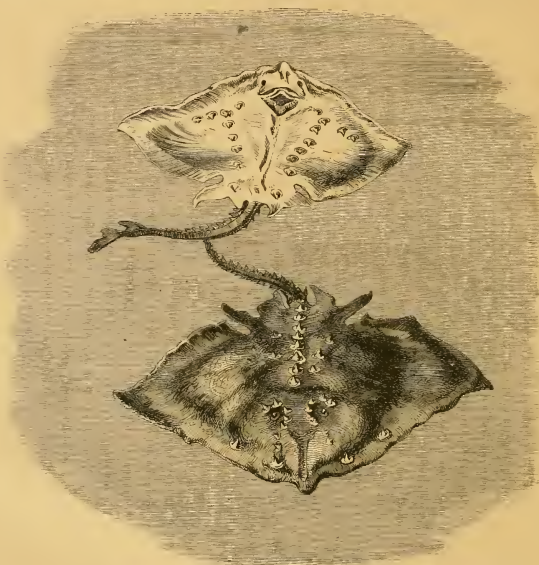
§ *Raja maculata*.

and hence is sometimes known as the Spotted Ray and as the Painted Ray. It is found nearer into shore than the Thornback, and deposits its eggs, which are smaller than those of the Thornback, in shallow water, so that they are often thrown on the beach in stormy weather. The young are hatched from November to January, and then have a breadth of three inches and a length of five inches, half of which is formed by the tail.

Closely allied to this British species is the Sandy Ray (*Raja circularis*), a variety of which, known as the Cuckoo Ray, has usually only two large spots on the back, while the *Raja circularis* has from eight to sixteen small spots, each about the size of a pea.

THE THORNBACK.*

The Thornback is one of the commonest of British Rays, and is taken all round the shores, on the Dutch coast, and along the Mediterranean Sea as far as the Golden Horn; and it is also met with at Madeira. It is of a dark-brown colour, with fainter-coloured spots. The whole upper surface



THORNBACK.

is covered with asperities, and a variable number of large spines like recurved nails, which are more abundant in the female than in the male, but always extend down the tail in a median line. In spring and summer it is taken abundantly, because it then comes into shallow water to deposit its eggs, but is in the best condition for table in November, though the flesh is firm throughout autumn and winter. It is a favourite food with fishermen, and is frequently salted; but in the Moray Firth

* *Raja clavata*.

it is preserved by pressure, large stones being heaped over the fishes to squeeze out the juices of the body, after which it is only necessary to secure the flesh from rain and moisture. The quantity taken depends a good deal upon the bait; the Pilchard and Herring always attract it, but it feeds on Crabs and other Crustacea, and according to Yarrell also upon Flat-fish and Mollusca. A specimen three feet two inches long was twenty-eight inches broad, and had the tail a foot and a half long. The teeth are rather large, but, like the spines and asperities, differ in character in the female and male. In the former all the teeth are flat, but in the latter the middle teeth are conically pointed. Nearly allied to this species is the *Raja radiata*, in which the large spines on the back attain greater dimensions than in the Thornback, and rise from an expanded base; the largest spines are in the middle line of the back and tail, and above the eyes. The shoulder-girdle of the Thornback is a nearly perfect girdle formed at the sides by the scapula and coracoid, with the ring completed by the epicoracoids below, and the supra-scapulae above, which latter bones abut against the spine of a neck vertebra.

In *Psammobatis*, which frequents the southern coasts of South America, the disc is perfectly circular and only five inches wide, the snout being very short. Each ventral fin is divided into two by a deep notch; the anterior portion is covered by the pectoral fin. Each nostril has two nasal valves. The tail is three inches and a half long.

Platyrrhina has a well-developed caudal fin, and is represented by two species from India and China, which both have the disc nearly circular.

FAMILY V.—TRYGONIDÆ, THE STING RAYS.

The Sting Rays form a large family, about twenty-four species of the genus *Trygon* being known, chiefly from tropical and sub-tropical seas, while the family includes, according to Dr. Günther, several nearly-allied genera, such as *Urogymnus*, *Taniura*, *Urolophus*, and *Pteroplatea*. The common Sting Ray,* like all the members of its genus, has the pectoral fins prolonged forward so as to unite in front of the head, while the tail is armed in its middle portion with a sharp, flattened, bony spine, serrated on both sides like a double-edged saw or harpoon. The spine projects upward and backward, and has the serrations hardened by an outer dense layer, so as closely to resemble tooth-structure. When the dart has become worn out, its attachment to the body is loosened, and after being cast off another one grows in its place. Occasionally the new spine protrudes from under the old one, which may be seven inches long in a fish measuring three feet. This fish was well known to the ancients, and regarded with dread on account of the supposed poison of its spine. It lives on shallow, sandy ground, rarely takes the bait, and is commonly caught by accident in nets. The flesh, when laid bare by skinning, is more than usually red, and is said to have a rank flavour. The species is comparatively rare on the British coast, but has a remarkably wide range being found in the Gulf of Mexico and on the northern coasts of South America, in the Canary Isles, and on the shores of China and Japan. *Trygon hystric*—a species frequenting the Brazilian coast—was taken by Mr. Bates, at Santarem, on the Amazons. *Trygon tuberculata*, a species which has the tail twice as long as the body, ranges from Sydney to the tropical parts of the Atlantic, and yet occurs in Lake Champlain. *Trygon hastata*, from New York, has the tail armed with two spines placed at a distance from each other. *Trygon rudis*, from Old Calabar, has the body six feet and a half broad, by four feet and a half long, while the tail measures fully six feet more. Usually the plates which carry the teeth are straight, or but gently undulating, but in the *Trygon sephen*, a species met with in the Indian Ocean and the Red Sea, the upper jaw is angularly bent, and receives the lower jaw—which is necessarily somewhat pointed—within this concavity. Rarely Trygons occur which have the body almost or entirely smooth, such as *Trygon nuda*. The longest-tailed species is *Trygon uarnak*, which has the body three feet long, with a tail nine feet long. The genus *Taniura* is represented by six species, some of which are found in the East Indian seas, and others in the fresh waters of tropical America, *Taniura motoro* being found in the River Cuyaba, in Brazil. *Urolophus* is a genus represented by five species, some of which are confined to the Australian seas, and others, like *Urolophus torpedinus*, are found in the West Indies and on the Pacific coast of Central America. In this genus the tail has a distinct terminal fin, with rays. The genus *Pteroplatea* has the body at least twice as broad as long, and the tail very short and

* *Trygon pastinaca*.

thin. There are half-a-dozen species from all the tropical and sub-tropical seas. The well-known *Pteroplatea altavela* occurs in the Mediterranean and on both sides of the Atlantic. Dr. Günther includes two genera in this family which want the bony spine on the tail. One of these—*Elipesus*—from the Rio Blanco, in British Guiana, has the tail very short, and distinct from the nearly circular disc. The other genus—*Urogymnus*—has a long tail, and a body densely covered with osseous tubercles. It is known only from the Indian Ocean.

FAMILY VI.—MYLIOBATIDÆ, THE EAGLE RAYS.

The Eagle Ray* is so named on account of the broadly-expanded pectoral fins, which closely resemble wings. The head projects well in front of them; the tail is twice as long as the body, slender like a whip, and, immediately behind the dorsal fin, carries a doubly-serrated spine. The eyes are placed so as to look laterally, and have been compared to those of an ox. The colour of the body is greenish or brown, and the skin is smooth. The palate consists of a succession of transversely elongated teeth, margined at the sides with smaller teeth. Specimens of the fish in the British seas have been estimated to weigh three hundred pounds, but the species is rarely taken. In the Mediterranean it is much more abundant, but the flesh, though sold in the Italian markets, is not held in great favour. Eagle Rays have been seen swimming on the surface of the sea, as have many other species of the same group, and they appear to breast the tide without difficulty. It is probable that the species is widely distributed, since it has been taken in the neighbourhood of Sydney, on the Australian coast. All the other species of the genus occur in Eastern seas, especially those of China, Japan, and the Indian Archipelago, though the *Myliobatis bovina* appears to be limited to the Mediterranean and adjacent parts of the Atlantic. In two species, both known from young specimens, the caudal spine has not been observed, and Couch records that it had not yet appeared in an embryo which he found still contained in the purse. He describes the purse in the British species as six inches and a half long and four inches and a half broad, with tendrils at the corners which were seven inches and a half long, and ended in a slender cord. The surface of the purse was marked with closely-set raised longitudinal lines, which were crossed by other lines and raised points. Towards the corners the reticulations form squares. The purse is nearly black. There are two other genera in this family—the *Aëtobatis*, which is distinguished by having broad, flat teeth, like those of the middle series of *Myliobatis*, without any lateral teeth; and *Rhinoptera*, which has no large median teeth, but has the jaw covered with polygonal plates, like a tessellated pavement.

THE OX RAY, OR SEA-DEVIL.†

The Ox Ray, or Horned Ray, differs from other Skates in having two processes prolonged forward from the pectoral fins, like horns. Its pectoral fins are even more expanded than those of the Eagle Ray, but on the other hand its tail is extremely short, and the dorsal fin is placed upon the hinder part of the body. It is brown above and white below. Its home appears to be in the Mediterranean, though specimens have been taken on the coast of Ireland. The flesh is red, dense, and difficult of digestion, but is eaten by the poor. In the Mediterranean, examples have been captured twenty-eight feet wide and twenty-one feet long, though this was said to be the smallest of a shoal. The fish was estimated to weigh a ton. The mouth is wide enough to swallow a man. The females are said to be larger than the males, and darker in colour. The young are produced in September, from eggs contained in long yellow cases. The species feeds chiefly upon Cephalopods and Fishes, and has been taken in nets arranged to catch the Tunny. The liver is large, and yields a quantity of oil. Dr. Günther describes the teeth as minute, extending nearly to the angles of the mouth, and arranged in more than a hundred and fifty rows. The number of rows of teeth is distinctive of the species. One with forty rows in the upper jaw occurs on the coast of Brazil, and others with thirty-four to ninety rows occur in the Indian seas, and one species ranges to Japan. In the nearly-allied genus *Ceratoptera*—which differs in having the teeth developed in the lower jaw only—an equally large size is apparently attained, for the *Ceratoptera campyrus*, which frequents the Atlantic and Gulf of Mexico, attains a width of twenty feet. A specimen fifteen feet wide, and as long, was between three and four feet

* *Myliobatis aquila*.

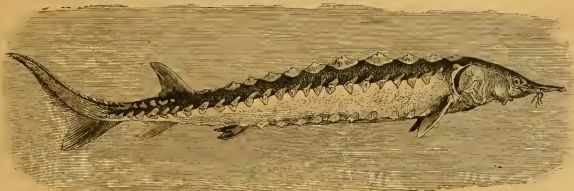
† *Dicrerobatis giornea*.

thick. It contained an imperfectly-developed young one, which was five feet broad, and weighed twenty pounds. A second species of the genus is recorded from the Red Sea.

ORDER V.—CHONDROSTEI.*

FAMILY I.—ACIPENSERIDÆ, STURGEONS.

The Sturgeons form a small and natural group of fishes, distinguished by having a cartilaginous skeleton. They have the head covered with bony plates, and the body armoured with five rows of bony bucklers, or scutes, which give it an angular character. The snout is pointed and conical. The mouth opens in a large but short tube below the eye on the under side of the head, and is destitute of teeth. Both jaws are formed of two cartilages, covered with a thin layer of bone. There are only two genera of Sturgeons known. Nineteen species belong to the genus *Acipenser*, while the second genus, called the Shovel-head (*Scaphirhynchus*), is represented by a single species (*S. cataphractus*), found in the Mississippi and its tributaries. It differs from the other Sturgeons in wanting spiracles, and in having the bony scutes uniting with each other on the hinder part of the tail, so as to envelop it in continuous armour. The nostrils in Sturgeons are double, and placed in front of the eye, and there are four barbels arranged in a transverse series in front of the mouth on the under side of the snout. There are no bony rays for the support of the gills, but there are four



COMMON STURGEON.

true gills and two accessory gills. The dorsal and anal fins are placed near to the caudal fin, which is unequally lobed or formed on the heterocercal plan usual among Sharks. Where the skin is not covered by the bony plates it is soft and covered with pores, which secrete mucus. The Sturgeons swim low, and feed on the decaying substances, animal and vegetable, which sink to the bottom of rivers and estuaries. These fishes have always been valued for their roe, which is known to us under the name of caviare. The eggs are deposited without being contained in cases, much in the same way as the eggs of bony fishes. A specimen which weighed 273 lbs. had the roe weighing 42 lbs., and in this there were computed to be two millions of eggs.

The life of the Sturgeon has been observed only after it has ascended rivers. It moves along with a gentle motion which suggests crawling rather than swimming, stirring up the mud and sand with its snout seeking for food. In the breeding season some species feed almost exclusively on small fishes allied to the Carp. They travel along the rivers between March and the latter part of autumn, but hibernate during the winter. Caviare is prepared from the roe in a very simple way. Usually it is beaten up and passed through a sieve to separate the eggs from the tissue in which they are contained. Salt is then added, and the eggs are packed in barrels for exportation. Another method of preparation is to remove the larger filaments of connective tissue, then salt, and dry in sun; it is next forced into barrels with the pressure of the feet. Better caviare is made by salting the roes in long troughs. They are then placed in fine sieve troughs, while the eggs are pressed through into small kegs. The best is obtained from the *Acipenser stellatus* and *Acipenser ruthenus*.

The fishing in winter is carried on, according to Brehm, in a singular way. The rivers are frozen over; and the fish which have hibernated bury their snouts in the mud so as to leave the

* Chondros, cartilage, and osteon, bone.

bodies sticking up in the water like the piles of a Swiss lake dwelling. The fisherman is armed with a pole, which is from twenty to sixty-five feet long, and terminates at one end in an iron rake. This instrument is put down through a hole in the ice, and the Sturgeon is speared. When one is caught the pole vibrates in the fisherman's hands, and he brings his capture to the surface. Sometimes days pass without a fish being taken, but often as many as ten may be landed in a day. On the Ural River 4,000 Cossacks in two hours have taken 40,000 roubles' worth of fish.

In summer fishing a portion of the river is hired from the landowner by the fisherman. He engages assistants, who may be Russians, Greeks, Tartars, Moldavians, or Poles, and provides boats and all requisites for the work, and builds large huts roofed with rush for the accommodation of his people, as near to the river as may be, but so placed as to escape floods. Each hut sleeps about twenty men. Salt is there stored in barrels, and mills are set up to grind it. The fish are captured in nets. If fishing is successful the men fare well; but usually their meals are of fish. A mast is set up on the bank with a look-out at the top, and here a man is placed to watch and give notice when the Sturgeon are seen coming up the river. Though often met with in the sea, the Sturgeon ascends rivers to deposit its eggs. Their numbers in many of the Russian rivers are almost incalculable. At Rubinsk, on the Volga, in the Russian government of Yaroslav, the fisheries draw together in spring and summer a hundred thousand people, who work continuously, and disperse to their homes in winter. When the fishing has been intermitted for a day the Sturgeons have been known to completely fill a river 360 feet wide and 28 feet deep, so that the uppermost fishes appeared with their backs above the water. Fifteen thousand have been taken in a single day. They occur in incredible multitudes in the Caspian, and are numerous in all the rivers of the south of Russia.

The Sturgeon is also valued for its air-bladder, which is a large simple bag that opens into the gullet. This is believed to enable the fish to vary the quantity of air which it contains, so as to influence the density of its body. The air-bladder is converted into isinglass. After being washed the bladder is turned inside out and dried. The internal membranes are then easily detached. It is again moistened and hung in the shade, and afterwards cut into strips, which are stretched on the bark of a tree to dry. The best isinglass is yielded by the Sterlet and by *Acipenser huso*. The Common Sturgeon of British seas (*Acipenser sturio*) is widely distributed over the world, being found throughout the Mediterranean and all round the western and northern shores of Europe, and along the eastern coast of North America. It is frequently taken in the Thames, but does not often reach a greater length than eight feet. A specimen eight feet six inches long, taken in the Findhorn, in Scotland, weighed 203 lbs. Pennant mentions an example caught in the Esk that weighed 460 lbs. In the Rhine it sometimes ascends to Mainz, and occasionally reaches Basel. It is also found in the Weser, Elbe, Moldau, Oder, and Vistula. The flesh is white and firm, and has a flavour that may be described as combining that of veal and lobster. It is often salted and preserved for winter use. Though an excellent fish, it never commands a high price in the London market. Yarell mentions that the stomach of one caught in the Tay was found to contain an entire sea mouse, the *Aphrodita aculeata*. Couch expresses an opinion that worms are probably their favourite food, but quotes a statement from an American newspaper that a lady's riding-whip, mounted with silver and twenty-one inches long, had been found in the stomach of a Sturgeon of moderate size. The snout is pointed. The barbels vary in position, being sometimes in front of the middle line between the eye and the end of the snout, and sometimes behind it. The dorsal shields, which are large, extend in the middle line of the back between the head and the dorsal fin. The lateral shields are as few as in any known species, varying from twenty-six or twenty-seven in young specimens, to twenty-nine or thirty-one in the adult. The skin is rough, with small star-shaped ossifications, which are arranged in more or less regular oblique series.

The *Acipenser huso* is a larger fish than the Common Sturgeon, reaching a length of twenty-five feet and a weight of 1,200 lbs. Its appearance is smoother than the Common Sturgeon, for though it also has five rows of angular scutes, extending down the body, each plate is smaller. There are about a dozen dorsal shields and forty to forty-five lateral shields. Some of the larger specimens have been found, according to Shaw, entirely destitute of armour, and with the skin smooth and slimy, so that the plates appear to drop off in old age, much as the hair sometimes drops off in man. The snout is short and three-sided, of a yellowish-white colour. The upper side of the body is dark

grey, but the plates are dirty white, like the under-side of the body. The barbels are flattened, and nearer to the eye than to the end of the snout. It is only occasionally found in the Mediterranean, and is otherwise confined to the Black Sea and Sea of Azov, and the rivers which flow into them.

The *Acipenser ruthenus*, commonly known as the Sterlet, is a small species, rarely more than twenty-one inches long. It has a narrow, pointed snout, which is somewhat elongated. The barbels are slightly fringed. The number of dorsal shields varies from eleven to fourteen. The lateral shields are more numerous than in any other species, and are from sixty to seventy in number. The skin is densely covered with minute ossifications, which are uniform in size. The back is a very dark grey, but the shields are whitish like the belly. It is found in the Black Sea, and in all the rivers which flow into it. It is a regular article of food at Vienna, is sometimes taken at Linz, and occasionally ascends as far as Ulm. It is abundant in the Caspian and the rivers that empty themselves into it; but less plentiful in the rivers of Siberia. It is believed to extend into the north-west coasts of America. *Acipenser ruthenus* deposits its eggs when the water has a temperature of 54° Fahr. The eggs are sometimes fecundated artificially in the Volga. The young are developed in seven days. They are at first a quarter of an inch long, but in ten weeks increase to a length of two inches, feeding chiefly on the larvæ of insects. They can live in fresh water only, but are hardy, and are often transported overland. In this way it was introduced long ago into Pomerania and Sweden. Several different species, distinguished by the form of the snout, the number of osseous shields, and the rays in the dorsal fin, occur in California, the Mississippi, and great lakes of North America. Other species are confined to the Atlantic coast of the United States. Sturgeons, however, are not found in North America north of latitude 54°, where the mean annual temperature is 33° Fahr. They are not often seen in clear cold streams, but make their way up many muddy rivers in such numbers as to form almost the only food of the Indian tribes during the summer months. The *Acipenser brevirostris*, which is usually from two to five feet long, is so abundant in the river Hudson as to be known in the markets under the name of Albany beef. One species (*A. sinensis*) is known only from China, and is reserved for the table of the Emperor. Two or three species appear to be limited to the Mediterranean, but the majority of Sturgeons are confined to the Black and Caspian Seas, and the rivers which flow into them.

FAMILY II.—POLYDONTIDÆ.

A second family in this order is formed for the Paddle-fish genus, named *Polyodon*. It is represented by two species, one (*Polyodon folium*) found in the Mississippi and its tributaries, the other (*Polyodon gladius*) occurring in the Yang-tse-kiang. The genus differs from the Sturgeons in having the skin naked, or containing only minute star-shaped ossifications. The snout is extremely long and shovel-like. It is covered with small star-like reticulations, and is regarded by Wagner as being a forward prolongation of the parietal region of the skull. The maxillary arch is fixed to the head, so that the mouth cannot be protracted as among the Sturgeons. The jaws are armed with minute teeth, and there are teeth on the palatine bones. There are no barbels, and there is no tongue, so that the sense of touch must be feeble. The fins resemble those of the genus *Acipenser*, except that the lower lobe of the caudal fin is nearly as broad as the upper lobe. The air-bladder is large and cellular, and opens into the œsophagus. There is hardly any separation between the œsophagus and the stomach; the pancreas is a short broad lobed organ; and the intestine terminates in a spiral valve. The cartilaginous rings of the vertebral column are more delicate than those of the Sturgeon.

CHAPTER III.

THE PLECTOGNATHI.—THE LOPHOBRANCHII.—THE ANACANTHINI.

THE PLECTOGNATHI—Singular Shapes of the Fishes of this Order—Their Characters—The Triacanthinae—The Balistinae—The File-fish—The Monacanthinae—The Ostracion—The Gymnodontes—The Genus Triodon—The Globe-fishes—The Genus Xenopodus—The Tetrodons—The Genus Diodon—Darwin on the Habits of a Diodon—Allied Genera—The Sun-fishes—The Common Sun-fish—Habits—Characters—The Oblong Sun-fish—THE LOPHOBRANCHII—Their distinctive Features—The Solenostoma—Characters—The Syngnathidae—Interest attaching to them—The Broad-nosed Pipe-fish—Description—The Great Pipe-fish—Habits—The Marsupial Pouch—Other Species—The Ocean Pipe-fish—The Worm Pipe-fish—The Sea-horses—Phyllopteryx—Dr. Günther's Account of its Spines and Filaments—The Genus Hippocampus—The British Sea-horse—Other Species—THE ANACANTHINI—THE COD-LIKE DIVISION—THE COD—Its Voracity—Its Fecundity—Tame Cod—Description of the Fish—The Cod-fisheries—Long-line and Hand-line Fishing—THE HADDOCK—A "Great Conchologist"—"St. Peter's Mark"—THE WHITING—Coach's Whiting—The Pollack—The Coal-fish—THE HAKE—The Greater Fork Beard—The Burbot—THE LING—THE MACKEREL MIDGE—The Silvery Gade—The Rocklings—The Tadpole Hake—THE TORSK—The Ophidiidae—Characters—THE GENUS PIETASPER—Distinctive Features—The Greater Sand Eel—The Lesser Sand Eel—THE FLAT-FISH, OR PLEURO-NECTIDE—Characters—THE HOLIBUT—The Largest of the Flat-fish—The Rough Dab, or Sand-sucker—THE TURBOT—THE BRILL—THE WHIFF, OR MARY SOLE, OR SAIL FLUKE—The Topknot—BLOCH'S TOPKNOT—The Scald-fish, or Megrin, or Smooth Sole—The Genus Pleuronectes—THE PLAICE—Favourite Fish of the Poor—Lacépède's Story about Shrimps and Plaice—THE DAB, OR SALTIE, OR SALT-WATER FLUKE—The Smear Dab—The Pole, or Craig Fluke—THE FLOUNDER—THE SOLE—THE LEMON SOLE—THE VARIEGATED SOLE—The Solenette—Trawl Fishing.

DIVISION II.—TELEOSTEI (BONY FISHES).

ORDER I.—PLECTOGNATHI, OR FISHES WITH JAWS UNITED.

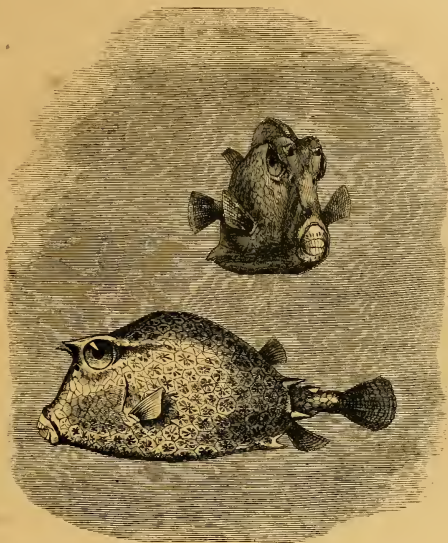
THE fishes which belong to this order present some of the most singular shapes which are known. The skin is sometimes covered with ossifications in the form of spines projecting all over the body, as in the Globe-fish; or it frequently, as in the genus *Ostracion*, forms a carapace, or bony box built up of scutes, which rather suggest the shield of a leathery Turtle than the covering of a fish. Often the jaws are formed into massive teeth, as in the genus *Diodon*, which rather suggest the beak of a bird; while many, like the Sun-fishes, are short-bodied, and are constructed on principles of symmetry very different from those which are usual in the group. The internal skeleton is often imperfectly ossified, and the vertebrae are few. There are no ventral fins, or they are represented by bony spines, but there is a soft dorsal fin opposite to the anal fin, and both are placed in the hinder region of the body. The air-bladder is always present, but is never connected with the throat by a pneumatic duct. The form of the jaws serves to divide the order into two groups. The family in which they form a beak has been named *Gymnodontes*, while that in which the jaws possess distinct teeth, has been termed *Sclerodermi*.

FAMILY I.—SCLERODERMI.

This family, as the name indicates, has the skin more or less covered with scutes or roughened with spines, and the snout is somewhat prolonged in front. Dr. Günther divides this family into three groups, which are named from typical genera—*Triacanthina*, *Balistina*, and *Ostraciontina*. The first group includes in all but five species and three genera; one of these comes from Japan, another from Cuba, while the *Triacanthus*, with its three species, ranges through the Australian seas to the north of China. In all these fishes the skin is covered with strong and rough little scutes. The ventral fins are formed by a pair of strong spines, which are joined to the pelvic bone. The teeth have the form of incisors, and there is an anterior dorsal fin with a few small spines behind a strong and large one. The second group—*Balistina*—has the body covered with scutes which are adjacent to each other, but movable. The teeth in the upper jaw form a double series of incisors, and in the lower jaw a single series. The first dorsal fin is reduced to three spines, and the ventral fin to a simple osseous spike. There are two important genera in this group, *Balistes*, with twenty-six species, and *Monacanthus*, with forty-one species. These are essentially fishes of tropical and sub-tropical seas, and the species often have a remarkably wide range. The single British species of *Balistes* illustrates this distribution, since it is met with in the Mediterranean, Atlantic, and Pacific Oceans.

Balistes capriscus is rather a rare capture on the British shores, but has been taken indifferently in the north of Scotland, the west of Ireland, and the English Channel. It has been named, from the toothed character of its dorsal spine, the File-fish, and from its very singular appearance, the Pig-faced Trigger-fish, though the latter part of the name is derived from the way in which the second

dorsal spine locks into the first. One of the most remarkable characters of the genus is a soft smooth furrow in front of the eye. There are shields behind the small gill-openings, and the face is usually covered with scales similar to those which exist on the body. There are no spines or tubercles on the tail. Thirty-two scales extend between the dorsal fin and the vent. The ventral spine is movable. Dried specimens are always brown, but Yarrell records that the living fish is turgid blue. An adult specimen has a length of fourteen inches; young specimens are sometimes marked with dark-brown spots. Some of the Eastern species, like the *Balistes niger* and *Balistes bursa*, have a series of



OSTRACON QUADRICORNIS.

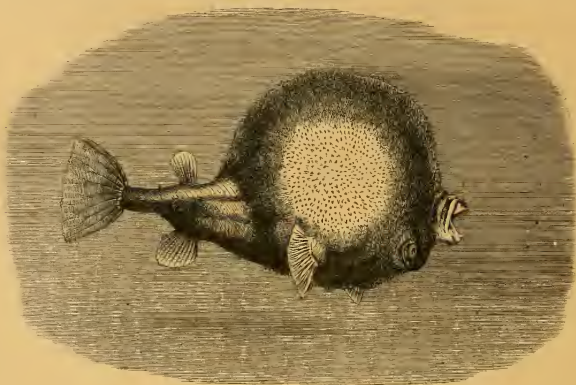
recurved spines on the tail. Other species, like the West Indian *Balistes ringens*, have longitudinal grooves on the cheeks. Several species have no groove in front of the eye, while the *Balistes erythrodon* has the teeth of a reddish-brown colour.

The genus *Monacanthus* has the body covered with very small rough scales. The ventral fin is usually fixed; the first dorsal fin is a single strong spine with a rudimentary spine behind it. In the *Monacanthus peronii*, and some other Australian species, the dorsal spine has four edges, which are at equal distances from each other, and each is barbed. In this species the spine is inserted above the middle of the orbit. The third group of the Sclerodermi contains only the Ostracion, which, however, is represented by about twenty-two species. These fishes are contained in a carapace formed of hexagonal plates which touch each other, but the snout, bases of the fins, and hinder part of the tail are covered with soft skin. The ventral fins do not exist. The maxillary and pre-maxillary bones have become blended together, and the jaw carries a single series of small teeth. There are only

fourteen vertebrae, the earlier ones elongated and the last five greatly shortened. The species are grouped into two sections—first, those in which the carapace is closed behind the anal fin; and secondly, those in which the carapace is open behind the anal fin. In some species the carapace has three longitudinal ridges, in others there are four, five, or even six ridges. Sometimes there are prominent spines which are conical, and project in front of the orbits, or from the ventral, or dorsal, or lateral ridges. None of these fishes attain a large size, the *Ostracion cubicus* having a length of fourteen inches, and the *Ostracion quadricornis* reaching a length of sixteen inches. *Ostracion bicaudalis* is seventeen inches long, but the *Ostracion renardi*, from Amboyna, is only about four inches long, and there are many other species of about this size. Like the other genera in this family, the *Ostracion* is most abundant in the Malay Archipelago, the West Indies, and tropical coasts of Africa. Two specimens of the *Ostracion quadricornis* have been taken near Mervagisey, on the Cornish coast.

FAMILY II.—GYMNODONTES.

This family, in addition to having a sharp cutting beak without teeth, formed of the bones of the fore part of the head more or less blended together, has the dorsal, anal, and caudal fins soft and approximating towards each other. The ventral fins are absent, but the pectoral fins are present. The



TETRADODON FAHAKA (FLOATING BELLY UPWARD).

first genus of this family, *Triodon*, is so named because the upper jaw is divided by a suture in the middle, while the lower jaw is entire, thus giving the aspect of three teeth, which are large, white, and have the appearance of being powerful cutting organs. The eye is large, being about one-fourth the length of the head. The nostril has two distinct openings on each side of the head. The most distinct characteristic of this fish is furnished by the abdomen, which is capable of being dilated into a large sack which hangs below the body. The air, however, does not penetrate into its lower part, and the sack is kept expanded by a very long pelvic bone. This fish is found widely distributed in the Indian Ocean, and reaches a length of twenty-one inches. The skeleton is well ossified and the ribs well developed, and the body is covered with small bony plates which are spiny.

The second group has *Tetrodon* for its type, and though called *Tetrodontidae* only, has both jaws divided in the two genera *Xenopterus* and *Tetrodon*, while the remaining six genera resemble *Diodon* in having no median suture in the jaws. These fishes are popularly known as Globe-fishes, from the well-known circumstance that after filling the body with air they float on the surface of the water

with the belly upward. *Xenopterus* is a genus of the Indian Archipelago, distinguished by its funnel-shaped nostril and the small dermal ossifications, which each have two or three roots and form spines over the skin. The *Xenopterus modestus*, which is about four inches long, is found in the rivers of Borneo and Sumatra, but the *Xenopterus naritus* has been met with indifferently in rivers and the Sea of Penang. The specimens from Borneo reach a length of eleven inches.

The large yellow *Xenopterus naritus*, which is found in the rivers of British Burmah, is considered to be excellent eating, but an allied genus (*Tetrodon*) from the Nile is known to be exceedingly poisonous. Dr. Day records that a species from Japan (probably a *Tetrodon*) is used for purposes of suicide, and that a law exists which prevents a soldier's son from entering the army when his father has terminated his days by feeding on this animal. The *Tetrodons* are generally reputed to be poisonous, but they are eaten by the Andaman Islanders, and the native doctors in Malabar prescribe them as a medicine.

The genus *Tetrodon* includes about sixty species, which are nearly all tropical, and by far the larger number are known from the Malay Archipelago and adjacent seas, though well represented on the African coasts. Several species inhabit fresh waters. In the first section of the genus the scutes form a continuous carapace round the trunk; the second group has a broad back and very prominent nasal organs situate on elevated papillæ, but there are no scutes forming a carapace. In many species the spines are limited to the belly; in others they occur on both the back and belly, but are absent from the sides. Some have the spines minute and invisible, so that the fishes are smooth to the touch; others, again, have no spines at all, but minute soft tubercles on the skin. A number of species have the back compressed into a keel, and in these the nasal organs are never prominent. *Tetrodon fluviatilis* occurs indifferently in the fresh waters and on the coasts of the East Indies. The little *Tetrodon erythrotenia*, two inches and a half long, is from the rivers of Amboyna and Celebes. The entirely naked *Tetrodon cutcutia*, four inches long, is from the Ganges. *Tetrodon fahaka*, which is one of the largest species, reaching a length of eighteen inches, occurs all up the Nile, in the Niger, and on the West Coast of Africa. The largest form, twenty-seven inches long, is the widely-distributed *T. sceleratus*, which ranges round the Indian Ocean and through Polynesia.

The only British species, *Tetrodon lagocephalus*, is also found on the south and east coast of Africa, as far as Mauritius. The back is a brilliant ultramarine blue; the belly and sides are silvery-white; while the fins and tail are brown. The abdomen is covered with spines from the mandible to the vent; each has four roots. The back is almost straight. The air-sac has a smooth internal surface, with two openings into the œsophagus, the first simple, and the hinder one valvular. One of these is probably used only to admit the air, and the other to discharge it. It has been found on the coasts of Cornwall and Ireland, the largest specimen being twenty-one inches long.

The genus *Diodon* differs from *Tetrodon* in little beyond the absence of the median suture from the jaws. The body is similarly covered with ossifications in the skin, each with a pair of lateral roots, and a stiff movable and erectile spine. The upper part of the body is usually dark and the lower parts white. The largest species (*Diodon hystrix*) is two feet to two feet six inches long. The four species are found in all the seas between the tropics, and all range to the Cape of Good Hope. There is no British representative of the genus. Mr. Charles Darwin remarks, in his "Voyage of the *Beagle*," as quoted by Mr. Yarrell:—"One day I was amused by watching the habits of a *Diodon* which was caught swimming near the shore. This fish is well known to possess the singular power of distending itself into a nearly spherical form. After having been taken out of the water for a short time, and then again immersed in it, a considerable quantity both of air and water was absorbed by the mouth, and perhaps likewise by the branchial apertures. This process is effected in two methods: the air is swallowed, and is then forced into the cavity of the body, its return being prevented by a muscular contraction which is externally visible; but the water, I observed, entered in a stream through the mouth, which was wide open and motionless; this latter must, therefore, depend on suction. The skin about the abdomen is much looser than that of the back, hence, during the inflation, the lower surface becomes far more distended than the upper; and the fish, in consequence, floats with its back downwards. Cuvier doubts whether the *Diodon* in this position is able to swim; but not only can it thus move forward in a straight line, but it can likewise turn round on either side. This

latter movement is effected solely by the aid of the pectoral fins, the tail being collapsed and not used. From the body being buoyed up with so much air the branchial openings were out of the water; but a stream drawn in by the mouth constantly flowed through them. The fish having remained in this distended state for a short time, generally expelled the air and water with considerable force from the branchial apertures and mouth. It could emit, at will, a certain portion of the water; and it appears, therefore, probable that this fluid is taken in partly for the sake of regulating its specific gravity. This *Diodon* possessed several means of defence. It could give a severe bite, and could eject water from its mouth to some distance; at the same time it made a curious noise by the movement of its jaws. By the inflation of its body the papillæ, with which its skin is covered, became erect and pointed. But the most curious circumstance was that it emitted from the skin of its belly, when handled, a most beautiful carmine-red and fibrous secretion, which stained ivory and paper in so permanent a manner, that the tint is retained in all its brightness to the present day."

There are five genera closely allied to *Diodon*. *Chilomycterus* possesses a species (*Chilomycterus geometricus*) which, though widely distributed in the tropical parts of the Atlantic, is found in Lake Champlain and several inland waters of the United States; but most of the species of this genus belong to the Indian Ocean and adjacent seas. In the genus *Trichodiodon*, which frequents the North Atlantic, the spines on the body are reduced to delicate hairs: an example in the Paris Museum has a length of thirty inches. In *Trichocycus* the spines become elongated like bristles, and the dorsal and anal fins are entirely absent.

The third division of the *Gymnodontes* contains only the Sun-fish; and this group, represented by a single genus, is named, from its typical species, *Molina*. The Sun-fishes belong to the genus *Orthogoriscus*. The body is short and compressed, and covered with a rough or tessellated skin, which is not capable of being expanded as among the *Diodonts*. The air-bladder is absent, there is no pelvic bone, the ventral fins are wanting, and the vertical fins are all placed together at the hinder part of the body, and often are so arranged that the dorsal and anal fins seem but lateral lobes of the caudal fin.

The Common Sun-fish (*Orthogoriscus mola*) inhabits the open sea, and has been met with in many parts of the world in temperate and tropical waters. It is not uncommon in Australia, where it is valued for the quantity of oil which it yields. Every year a few specimens are taken during the warmer months on some part of the British coast, even as far north as the Orkneys. It is usually captured floating on the surface, when it appears languid and almost asleep, with its head projecting out of the water, but it is sometimes found lying on its side, and is then probably sick, though the fishermen regard this as an indication of continued fine weather. In this state it is not alarmed by the approach of the fisherman, though, when the opportunity offers, it makes its escape over the surface faster than a rowing-boat can follow. When laid hold of these fishes utter sounds which some fishermen have compared to the loud grunting of a hog. When anything approaches the eyeball, the ball is drawn into the socket, and a membrane rises up from the base and covers it. The Sun-fishes appear to retain their vitality for some time out of water, for a specimen kept in a boat for half an hour, on being thrown back into the sea is said by the fishermen to have darted away like an arrow. Couch mentions, on the authority of a friend, that when cooked for the table it is good eating, and has much the flavour of the Common Crab, but in England no use is made of it. Its food is variable, and the stomach has been known to contain seaweed, corallines, and barnacles, though nothing but mucus is usually found there. Sometimes the species reaches an enormous size. The largest British specimen known is seven feet nine inches long, and eight feet six inches deep across the fins, but the proportions change with age, and in very young examples the vertical diameter exceeds the length, while in older examples the depth is somewhat more than half the length. With age a lump is developed above the mouth, and on this there is a bony tubercle, while in very young specimens this position is marked with a spine. Young examples, too, have spines scattered over the body, and in the region of the throat some of these are converted into osseous tubercles, and remain throughout life. The teeth undergo a remarkable modification. In the young state there are supplementary teeth within the cutting jaws, and these teeth are generally met with till the fish attains a length of eighteen inches, but when the animal has become twice as long they have entirely disappeared. The head is thicker than the body, and has an elevated ridge above the eye. The small mouth is placed below the blunt nose, and is capable of but little movement. Each jaw has the

surface of the bone covered with enamel. The openings of the gills are small, nearly vertical, slits just in front of the pectoral fin. The vent is prominent, the dorsal and anal fins are triangular at the base, and greatly elongated; they join on to the caudal fin, which is narrow, and not very conspicuous, though it runs the depth of the body. The back and fins are usually almost black, but the belly is a brilliant white. Couch mentions that some small specimens have beautiful variations of colour in stripes, with blotches of blue, yellow, and white. The stomach is long and large, the intestine thick, and convoluted into a ball, and there is a large urinary bladder which communicates with large kidneys by two ducts. The Sun-fish is usually infested with parasites, which are found in the gills and on various parts of the skin.

The Oblong Sun-fish (*Orthogoriscus truncatus*) has the height of the body less than one-half its total length. The mouth is about level with the eye; the smooth skin is divided into small hexagonal scutes. A specimen taken at Plymouth in 1734 weighed 500 lbs., but it is not often met with of a large size. It lives on worms, sea-shells, crabs, and other marine animals. A young specimen twenty-five inches and a half long had the body twelve inches and a half deep, and the height, from the tip of the dorsal fin to the tip of the anal fin, was twenty-one inches and a half. On this specimen there were wavy vertical stripes both on back and belly; only on the back they appear as silver streaks on a dusky brown surface, and on the belly as greyish-brown streaks on a surface of silver. It has never been noticed basking in the sun like the Broad Sun-fish. The caudal fin is more distinct in this species, and the dorsal and anal fins form continuations from it. The pectoral fin, which in the Broad Sun-fish is rounded at the extremity, in this species terminates in a point. It is very rarely met with, but has been found in the English Channel, Bristol Channel, and the northern coasts of Scotland, and ranges along the west coast of Africa by Sierra Leone and the Cape Seas, and has been met with in the Pacific. A third species of Sun-fish (*Orthogoriscus lanceolatus*) is recorded from Mauritius. It differs chiefly from this in having the caudal fin as long as it is deep.

ORDER II.—LOPHOBRANCHII,* OR FISHES WITH TUFTED GILLS.

The most remarkable characteristic of this order of fishes is found in the form of the gills, for instead of being pectinated, or shaped like a series of combs, as in other fishes, they consist of small rounded lobes clustered together, so as more to resemble the appearance of minute mulberries, and yet are attached to the branchial arches. These gills are protected by a single large plate, which is the only representative of the operculum. The snout is produced into a tube, and ends in a small toothless mouth. The air-bladder, when present, is simple, without a pneumatic duct connecting it with the œsophagus, though in one species Dr. Günther has found a band leading from the œsophagus to the air-bladder, which probably indicates the former existence of a duct, which has become obliterated. There are only two families in this group, which are named Syngnathide, comprising the Pipe-fish and the Sea-horses, and the Solenostomide, which contains only the genus *Solenostoma*.

FAMILY I.—SOLENOSTOMIDÆ.

This family is distinguished by the great width of the openings into the chambers containing the gills, and by possessing two dorsal fins, with firm unjointed rays in the first fin, while all the other fins—pectoral, ventral, anal, and caudal—are well developed. These characters easily separate *Solenostoma* from the Pipe-fishes. Of *Solenostoma* only three species are known. The genus has a very simple intestine, dilated somewhat, so as to form a stomach, but without any appendages in the pyloric region, so that the function of the pancreatic secretion in assisting digestion must be rendered unnecessary by the nature of the food on which these animals subsist. The air-bladder is absent. The ventral fins, which are opposite the anterior dorsal, are free in the male, but in the female their inner margins are united with the covering of the body, so as to form a large pouch into which the eggs are received to be hatched. The inner walls of this sac are lined with long filaments, which are arranged along the seven ventral rays in series, and are most numerous at the base of the rays. There is a canal in the interior of each filament, which may furnish a secretion for the attachment of the embryo. The largest filaments have a length of half an inch, and are covered with little appendages like mamme. The filaments are most developed in fishes which have already deposited

* *Lophos*, a tuft; *branchii*, gills.



BROAD-NOSED PIPE-FISH.

the minute eggs in the sac. The vertebral column consists of eighteen abdominal vertebrae and fifteen caudal vertebrae. The vertebrae gradually decrease in length backward, so that the shortness of the tail is due to the diminished length of the bones. The pelvis consists of two pairs of cartilaginous plates. There is a dermal skeleton on this fish, formed of star-shaped ossifications, each having three or four radiating branches, by which they are joined to the adjacent bones. *Solenostoma cyanopterum*, which ranges from Zanzibar to China, varies in colour, being sometimes brown, with minute spots of black and white, and sometimes pink, with small brown spots. The other species are from Amboyna.

FAMILY II.—SYNGNATHIDÆ.

The Syngnathidæ are all marine, though many species enter fresh waters. They are widely distributed over the world, but limited to the temperate and tropical regions. The openings for the gills are very small, and placed at the upper angle of the hinder margin of the gill-cover. There is only one dorsal fin, and that is soft; there are never any ventral fins, and in some examples the other fins disappear. There are two divisions of this family represented by the Pipe-fish and the Sea-horse. Of Pipe-fishes there are ten genera, and of Sea-horses five. Notwithstanding the marvellous appearances which the Sea-horses assume from the circumstance that the tail is prehensile and without trace of a caudal fin, and serves the purpose of a hand as efficiently as the tail of a monkey, the Pipe-fishes perhaps present circumstances in their history of still greater interest. The whole of the male Pipe-fishes perform the office of hatching the young in pouches on their own bodies, though in two genera named *Nerophis* and *Protocampus* the pouches are wanting, and the eggs are attached to the loose skin of the abdomen in the male. These two genera want the pectoral fin, and the caudal fin is sometimes absent, and sometimes represented by a rudiment. Some of the genera have the egg pouch for the male, which is usually closed after the eggs are received into it, situate upon the abdomen, while in other genera it is situated upon the tail.

The Broad-nosed Pipe-fish (*Siphonostoma typhle*) is found on British shores and all round the coasts of Europe, ranging into the Mediterranean and Black Sea, and as far north as Sweden. Its prevailing colour is olive-green, mottled with pale and dark shades of yellow. The usual length is a foot to fifteen inches, though Yarrell speaks of specimens eighteen inches long, and quotes Bloch as attributing a length of two or three feet. They have been taken in shallow water, where the bottom is covered with weeds. The humeral bones in this genus are movable, and are never united together to form a bony ring, as in the other Pipe-fishes. The trunk is sheathed in a series of eighteen bony rings, and the series is prolonged by about thirty-five smaller rings which cover the tail. The tail is four-sided, and terminates in a pointed caudal fin, which has the shape of a partly-opened fan. The genus *Syngnathus* is represented by forty-four species, many of which belong to the Malay Archipelago and Eastern Seas, several are African, a few American, and two or three are found in the Mediterranean. On British shores the Great Pipe-fish, or Needle-fish, Sea-adder, or Tangle-fish (*Syngnathus acus*), is met with chiefly in bays and harbours. They are usually seen together in pairs, and feed on stony ground or among overhanging weeds. Sometimes small Shrimps are swallowed by them, for though the mouth is small it admits of being considerably enlarged by the action of muscles on the bones. The nostrils are close in front of the large eyes. The body is considerably lengthened, and tapers behind the dorsal fin in the female, and behind the marsupial pouch in the male. Behind the dorsal fin the body is square; in front it has seven ridges, three on each side, and a median ridge in the middle of the back. It is covered with a series of bony plates, of which there are twenty in front of the vent, and forty-four on the tail. The colour is a rich yellowish-brown, often mottled. In the young the snout is short, and the body has many fewer osseous rings; there are also fewer dorsal rays, and the lateral line is more frequently continuous with the upper edge of the tail; but when the fish gets to be more than eight inches long the characters of the adult become developed. The young fishes possess the power of reproduction; the ovaries of the female are always found well developed, and the pouches of the males, which are said by Dr. Günther to be nearly as long as the part of the body in front of the vent, are filled with eggs when they are mature. The pouch is not very deep; before the eggs are impregnated its entrance is sealed up; after the eggs have been received into it, which is a process extending over some little time, it is again sealed up by a glutinous secretion, similar to that by which the ova are held to its walls. Eggs have been found in the pouch as early as the beginning of winter; but some of the young in it are found fully developed, while others were just showing the rudiments of the snout and the eye. Couch records that in April he found the ova in the pouch all closely fastened together and attached to its walls at the sides and back, so that each egg was contained in a cell. The eggs were formed of transparent fluid, with a red spot on one side; this spot is always directed towards the opening of the pouch. Even when fully developed there is a kind of attachment between the parent and the young, and after they have escaped into the water they seek the shelter of the pouch when alarmed. The roe has been found developed in examples only four inches long.

The *Syngnathus algeriensis* is a fresh-water species from Algiers. The *Syngnathus specifer* was obtained by the Livingstone Expedition from the Rovuma River, and the *Syngnathus martensii* is found in fresh water in Borneo. The genus *Ichthyocampus* is characteristic of the Indian and China Seas, the genus *Nannocampus* is from Australia, and the genus *Urocampus* from Manchuria. *Doryichthys* is a genus with twenty species from tropical seas, some of which are taken in fresh water, like the *Doryichthys mento* from Celebes, and the *Doryichthys caudatus* from the island of Samar. *Doryichthys pleurostictus* is from the fresh waters in the island of Luzon in the Philippines. *Caelonotus* is a genus from the Indian Ocean, with one species entering fresh waters. *Stigmatopora* is from the Australian Seas. *Nerophis* is eminently a European genus, though one of its seven species is from Bombay, and another from Bogotá. *Nerophis teres* is from the Crimea, but *Nerophis lumbriciformis*, *Nerophis ophidion*, and *Nerophis aquoreus* are all British forms, ranging to the northern seas of Europe, though the last-named is also recorded from New Orleans. *Nerophis* has a smooth rounded body, with scarcely any traces of the ridges so characteristic of Pipe-fishes, and, as already remarked, the pectoral fin is absent, the caudal fin a mere rudiment, while the tail tapers to a point, and there are no lateral folds on the abdomen to protect the eggs, which are nevertheless carried by the male; and the anal fin is wanting.

The Ocean Pipe-fish (*Nerophis aquoreus*) is often seen by fishermen from thirty to fifty miles from land, but it has been observed to spawn in June and July in Dingle Harbour. The species clings by its tail to the tufts of *Zostera marina*, and in calm weather specimens may be seen side by side, and in this position the eggs are transferred from the female to the male. Couch mentions a female thrown on shore in a storm, which measured twenty-two inches long and an inch in depth, and a male twenty-six inches long. The upper part of the sides and tail are of a light reddish-brown, and the head and belly golden yellow. A specimen kept in the vivarium of the Scarborough Museum passed most of its time on a branch of *Laurencia pennatifidia*. When dead it was found with its head uppermost, in the same position as in life. Couch says that this species often abounds in incalculable numbers in the open sea, and that the stomachs of other fishes like the Pollack are found gorged with them. The male has a hemispherical depression on the abdomen in front of the vent, and in this hollow the eggs are attached. They are not easily detached, and the skin rises round each like a cup.

The Worm Pipe-fish (*Nerophis lumbriciformis*) does not exceed a length of five inches. Professor Fries records that when first hatched this species possesses pectoral fins, and there is a fin-like membrane at the tail which extends up the abdomen to the vent, as well as along the back. All these fins, except the portion which becomes developed into a dorsal fin, are afterwards cast off like the tail from the tadpole.

The group of Pipe-fishes, popularly called Sea-horses, usually have filaments attached to various parts of the body, and have the head set on to the trunk at an angle which suggests the comparison with the horse. The body is deeper and shorter than in the typical Pipe-fishes, and is encased in a succession of shields forming rings of jointed armour round the body, which are distinctly marked. The males similarly carry the eggs. The genera *Gastrotekous* and *Solenognathus* occur in the Australian Seas, and range north to China. The genus *Acentronura* is only known from Japan. *Phyllopteryx*, an Australian genus with three species, is one of the most wonderful of fishes in appearance; for, as the name implies, it has very much the aspect of a moving plant. The body is usually compressed, and the snout is long. Dr. Günther, who has described the *Phyllopteryx eques*, gives the following account of the spines and filaments which cover it:— "There is a pair of small spines behind the middle of the upper edge of the snout, a pair of minute barbels at the chin, and a pair of long appendages in the middle of the lower part of the head. The forehead bears a broad, erect, somewhat four-sided crest, behind which there is a single shorter spine. A horizontal spine extends above each orbit. There is a cluster of spines on the occiput, and from these narrow appendages are prolonged. On the nape of the neck is a long spine, dilated at the base into a crest, and carrying a long forked appendage. The back is arched, and on the under side are two deep indentations. The spines on the ridges of the shields are the strongest; they are compressed, are not flexible, and each terminates in a pair of short points. There is one pair of these spines in the middle of the back, and one on each of the three prominences of the abdominal outline; they terminate in flaps, which are long and forked. There are also very

long compressed flexible spines without appendages, which extend in pairs along the uppermost part of the back, while a single series extends along the middle line of the belly. Small short conical spines run in a single series along the middle line of the sides, and along the lateral edges of the belly; and there is a pair of similar spines in front of the base of the pectoral fin. The tail, which is about as long as the body, carries the dorsal fin; it is quadrangular, and has sharp edges. It carries along its upper side five pairs of band-bearing spines, which terminate in branching filaments."

Hippocampus is a genus found in the open seas in all temperate and tropical regions. The fishes attach themselves by the prehensile tail to seaweed, or any floating substance, and thus become drifted by currents over great distances. There are eighteen species admitted by Dr. Günther,



PHYLLOPTERYX. (From the "Proceedings of the Zoological Society.")

but he remarks that the length of the snout, the shape of the shields, and the development of the tubercles, show such an amount of variation as to make great difficulties in determining the species. The body is compressed from side to side, and formed of ten or twelve rings, behind which is the four-sided tail. The shields are armed with spines or tubercles, and at the back of the head there is a prominent crest, which terminates in an elevated knob, or coronet. There are also eminences above the eyes, in the temporal region, and at the base of the pectoral fins. The males carry the eggs in a sac at the base of the tail, opening near the vent. The females have a small anal fin.

The British Sea-horse (*Hippocampus antiquorum*), which is rare off Britain, is much more abundant in the Mediterranean, and has been found on the west coast of Africa, and the northern shores of Australia. It has often been kept in confinement. When swimming, the position is vertical, with the head more or less bent, though the angle is then rarely so great as in dried specimens. When several are together they frequently twist their tails into a band, and thus attach themselves the more firmly. This species is of a dark olive-brown colour, with bluish-white spots, and lines on the sides and tail. The eyes move independently. On the coast of Ireland specimens have been taken from the stomach of the Cod.

Some of the species vary considerably in colour; thus, *Hippocampus guttulatus*—a species with seventeen rays in the dorsal fin—is sometimes black, with brown cross-bands; other specimens are light or dark-brown. Sometimes brown specimens have a black head and a black tail, or the body may be marbled with a dark tint, and dotted over with black spots and smaller spots of white. Most of the species are from the Australian, Malayan, China, and Indian Seas, and vary in length from two to about six inches, though the *Hippocampus longirostris*, from the China Seas, reaches a length of eleven inches. These fishes may be termed the marsupials of the sea, and Yarrell compares the pouch in which the eggs are borne to the fold of skin in which the Wandering Penguin carries its solitary egg in safety over the great wastes of waters.

ORDER III.—ANACANTHINI, OR SOFT-FINNED FISHES.

Dr. Günther divides the fishes which have no spiny rays in the vertical and ventral fins, and which have the ventral fins, when present, placed under the throat, into two principal groups, which are typified by the Cod and the Sole. This order of fishes has been named Anacanthini. When the air-bladder exists it never communicates by a pneumatic duct with the fore part of the throat.

SUB-ORDER I.—GADOIDEI.

The Cod-like division is subdivided into six families, according to the position and degrees of development of the fins.

FAMILY I.—GADOPSIDÆ.

This family is known only from a single genus (*Gadopsis*), which is found in the fresh waters of South Australia and Tasmania, and has the fins formed partly of spines.

FAMILY II.—LYCODIDÆ.

This family includes but three genera, and one of these (*Gymnelis*) is met with on the south coast of England. It is commonly known as the Beardless Ophidium, and is the *Gymnelis imberbis*. In this genus the body is generally naked and elongated; there is no air-bladder; there are six branchiostegal rays; the vertical fins are united so as to extend down the back, and there are no ventral fins. The British species is rare, and is about three inches long and about a quarter of an inch deep.

FAMILY III.—GADIDÆ, THE COD FAMILY.

The Cod family includes twenty-one genera, in all of which the somewhat elongated body is covered with small smooth scales. One, two, or three dorsal fins occupy the whole length of the back, and there are one or two anal fins between the vent and the tail. The caudal fin, or tail, is separated from both the dorsal and anal fins; the ventral fins are placed on the under side of the throat. These fishes all inhabit the Arctic and temperate seas.

THE COD (*Gadus morrhua*).

The Cod is everywhere a voracious fish, taking almost any bait that may be offered, but feeding chiefly on crustacea, shell-fish, worms, and small fishes of various kinds. The natural feeding-grounds are elevated plains, or hills on the sea-bed, where they find their food on the bottom, guided by the sensitive barbel, which hangs from the under lip. As an instance of their voracity, it may be mentioned that Mr. Couch took thirty-five crabs—none smaller than half-a-crown—from the stomach of one Cod, and he records eighteen different species of crabs, and twelve long-tailed crustaceans allied to the lobster, as having been found at different times in the stomachs of Codfish in the English Channel. Their digestion is rapid, and the brittle crust of the crab is soon so far dissolved by the gastric juice as to become flexible. The Sea-Mouse, various bivalve shells, and stones encrusted with Lepralia and other Polyzoa, all contribute to satisfy the hunger of the Cod, though it can only be presumed that after the Polyzoa have been dissolved the stones are ejected from the stomach. The records of the fish upon which they feed are not numerous, but in one case six Picked Dog-fishes, each nine inches long, were found in the stomach of a Cod.

The fish are most prevalent at a depth of from twenty to fifty fathoms, and extend throughout the North European Seas, from Iceland as far south as Gibraltar, but the species does not enter the Mediterranean. A peculiar variety is found on the coast of Greenland. The species extends along the North American coast southward as far as New York. The Cod is in the best condition

for table while the roe is ripening. The eggs are shed in December and January, and after spawning the fish loses its flavour for some time. This species is one of the most prolific of fishes; the roe is often heavier than the entire weight of the remainder of the fish; but in an individual weighing thirty pounds, with a roe of only four pounds and a quarter, it has been calculated that there were as many as 7,000,000 eggs. In some cases the number may be 9,000,000. By the end of May the young are nearly an inch long, but they are never fit for market till the second year. The largest Cod caught on the Newfoundland banks occasionally reach a hundredweight, but the heaviest met with on British shores, caught between the Scilly Isles and Cornwall, have not weighed more than fifty-six pounds.

Yarrell mentions that in some parts of Scotland, as in Orkney, Fife, and Galloway, Cod have been kept in salt-water ponds which communicate with the sea by natural fissures. Here they become quite tame, and greet with open mouths the keeper who brings them boiled whelks and limpets. One is mentioned as having lived at Logan, in Galloway, for fifteen years. The Cod thrives well in confinement, and in one case, where they were retained in a pond separated from the Firth of Forth, they fed readily on sprats, young herrings, and other small fish, and devoured with evident relish the intestines of sheep. The Cod fishery has been carried on in the German Ocean since the latter part of the fourteenth century. The fish has long been found on the coast of Norfolk, Lincoln, and Northumberland, and especially on the Dogger Bank. It abounds around the coast of Ireland, and particularly on the Rockall Bank. The banks of Newfoundland and adjacent coasts have been fished since the year 1500. Here one man may take upwards of five hundred fish in a day, and in a year he is reckoned to capture ten thousand, though sometimes fifteen thousand may be caught in a single voyage. The present writer has seen small Cod caught in the Thames between Woolwich and Gravesend. When Cod are of the size of Whiting they are termed Codlings and "Skinners;" when they are larger they are known to the fishmongers as "tumbling" or "Tamlin" Cod. Of late years a considerable industry has been developed in the manufacture of oil for medicinal purposes from the livers of the Cod, but after spawning, the liver yields no oil. These fish are said to be chiefly caught for this purpose on the Newfoundland Bank. The air-bladder of the Cod is remarkably thick, and is termed the "sound." When pickled or smoked it is valued as a delicacy, and is cooked by boiling. Large numbers of Cod are dried and salted, and thus become distributed to many countries where the fresh fish could not be taken. The Cod caught on the Dogger Bank usually have the nose somewhat elongated in front of the eye, and the body of a dark-brown colour, and this variety extends all round the southern coast of England; but in Scotland the fish has a round, blunt nose, and the body is of a light-yellowish ash-green colour. Both varieties have the lateral line white like the belly. All the fins are dusky, and the upper part of the body and head are generally mottled and spotted. The head is large, and the breadth of the orbit of the eye is one-sixth of its length. The depth of the body is equal to the length of the head, and the length of the head is to the length of the body, exclusive of the caudal fin, as one to two and a half. The first dorsal fin begins just behind the origin of the pectoral; the second dorsal commences over the anal aperture. The third dorsal and second anal fins begin and finish at the same points. The tail is nearly square. There are fifty vertebrae.

Long-line fishing for Cod is carried on by large smacks, which are manned by from nine to eleven men, and remain at sea till a good cargo has been caught. Many of these boats use as many as 180 lines, each forty fathoms long. Each of these lines has a number of smaller lines attached to it, at a fathom and a half apart, and on these the hooks are placed. The total length of these lines is about eight miles, and they carry 4,680 hooks. The hooks are baited with whelk. The lines are shot into the sea about sunrise, and are laid across the tides so that the short lines, which are called snoods, may be carried away from the main line. No floats of any kind are used to raise the line from the ground, but at every distance of forty fathoms a little anchor is placed to keep the line steady, and at every mile of the length, and at the two ends, a conical buoy with a flag-staff is placed. The line is thrown out at half tide, and hauled up when the tide is nearly done. The fish are taken off the hook, have the air-bladder punctured, and are then put into the well of the ship, which occupies its central part. A constant supply of fresh water from the sea comes in through holes bored below the water line, and here the Cod will live for a long time in fair weather. If they die from being knocked

about by the rolling of the ship they are at once taken out from the well and packed in ice. Frequently a smack comes in from the Dogger Bank with twenty or more score of live Cod, and with more than half as many packed in ice. A smack with a well of this kind costs about £300 more than an ordinary vessel, so that a boat of sixty-eight tons costs £1,500. More than half the hands on board a Cod smack are apprentices. The captain is paid nine per cent. on the proceeds of the voyage, the mate gets £1 2s. a week, and the men £1 a week each. The apprentices are paid from £4 to £10 a year. The food for the crew is found by the owner. The Whelks used for bait are largely caught in the Boston and Lynn deeps, and on the Kentish coast. The long line is used to catch them, but instead of baiting the hooks, about twenty shore crabs are threaded on each snood, and when the lines are hauled up they are found to be covered with Whelks. The Whelks are also captured by putting refuse fish in shallow nets, which are sunk to the bottom. Each smack takes with her for the voyage about forty wash of Whelks, the wash being a regular measure which holds twenty-one quarts and a pint of water. The Whelks are preserved alive in bags in the well till they are wanted. The shells are then broken and the animals taken out for use. The long-line fishing season is carried on on the Dogger Bank from November to March or April, and on the Cromer Knoll from November to February. A few Cod are caught a little later on the Dutch coast, but many of the smacks then go to Iceland and the Färöe Isles, where the long-line is no longer used, and the fish obtained are salted.

From July to about the end of October Cod are fished for with a hand-line, at a distance of about ten to thirty miles from the coast, for the Cod are then following the Herrings. The only difference in the fishing is in the character of the line used. The hand-line has a sinker of lead at the end, weighing six or seven pounds. Through the upper part of this a stout iron wire passes, curving downward at the ends. To each end of the wire a smaller line or snood six feet long is fastened. The hooks are twice as large as those used with the long-line, and are fixed so that the fish cannot bite them off. There are from two to six hooks on each line. The total length of the hand-line is about forty-five fathoms. Each hand in the smack works one line, and its depth from the surface depends upon the position of the fish in the sea. The fish bite best towards sunset. About half of those caught are only half grown, but there is no reason to suppose that this destruction of young fish affects the supply for the market. When the ships arrive in port the Cod are taken from the well with landing nets and put into wooden chests, which at Grimsby and Harwich are kept floating in the water. Each chest is seven feet long, four feet wide, and two feet deep. The planks of which it is made are a little way apart at the sides and bottom to allow the water to pass freely through. A chest will hold forty large Cod, or a hundred small ones, and the fish remain alive in these boxes without deteriorating for about a fortnight. They are sent by rail to London and other markets according to the demand. But before this is done the chests are hauled out of the water and opened, one man grasping a fish by the head and tail, lifts it on to the deck, another acting as executioner, holds it firmly behind the head, and hitting it on the nose with a short bludgeon kills it at once. This is found to improve the flavour, and is thought to be more humane than to allow the fishes to die from suffocation, as they would do if sent off alive.

THE HADDOCK (*Gadus aeglefinus*).

The Haddock is a migratory fish, ranging round the British coasts, the German Ocean, and the American shores of the North Atlantic. In this species the barbel is very short, and the upper jaw protrudes in front of the lower jaw. The head is relatively smaller than in the Cod. The lateral line is black; below the lateral line and between the pectoral fin and first dorsal there is a blackish blotch. Dr. Günther remarks that the skeleton may be readily distinguished from that of the Common Cod by the transverse processes of the abdominal vertebrae being much longer than the neural spines. Haddocks swim in vast shoals, and often change their feeding-ground. Their habits are very similar to those of the Cod, and the species is usually taken with the hand-line, or long-line, baited with Herring. The stomach most frequently contains univalve and bivalve shells. Edward Forbes pronounced the Haddock a "great conchologist," and Mr. Couch mentions that in a single stomach he was able to distinguish no less than twelve species of univalves and bivalves. The most frequent size of the Haddock is from two to four pounds; less frequently they attain a weight of eight or ten pounds, and occasionally a length of two feet, but on the Irish coast specimens have been recorded by Mr.

Thompson weighing as much as twenty-five pounds. They are found all round the shores of Britain, but are most abundant on the east coast. Occasionally from some unknown cause the whole surface of the sea is found covered with dead Haddocks. When kept in confinement in the salt water preserves of Scotland the Haddock becomes so tame as to take limpets from the hand. The dark patches on the shoulders are popularly attributed to the impression which St. Peter left upon it with his finger and thumb when the tribute money was taken from its mouth, the mark having been continued ever since the miracle to the whole race of Haddocks; but unfortunately for this explanation the Haddock does not exist in the sea of the country where the miracle was performed. The upper parts of the body are of a dull greyish-white, and the white belly is slightly mottled with grey.

The Whiting Pout (*Gadus luscus*), and the Power Cod (*Gadus minutus*) are species well known on the British coasts.

THE WHITING (*Gadus merlangus*).

The Whiting is met with in all the coasts of Northern Europe, and is caught in great abundance about British shores, especially in the West of England and South of Ireland, but becomes rarer in the far North of Scotland. It is less gregarious than other species of its genus, except towards spawning time, in spring, when it assembles in schools. The species is fished for nearly all the year round, for the fish are much less exhausted by spawning than the Cod. They are taken in the largest numbers in January and February, when they approach within half a mile of shore, and seldom extend farther than three miles from land. The usual size is from twelve to sixteen inches, when the fish weighs from a pound to a pound and a half; but specimens occasionally reach the market which weigh as much as three or four pounds. Whiting prefer sandy bays, but as they feed greedily on the fry of other fishes, they often follow them for considerable distances. They are caught with the line, baited with the common mussel, or a slice of cuttle-fish. Fishing is most successful in the early morning and in the evening. Couch mentions as an example of the voracity of the fish, that four full-grown Pilchards were taken from the stomach of a Whiting that weighed four pounds. This species is

especially esteemed for food for the ease with which it is digested; but as it keeps but a short time, large quantities are salted and dried. The demand for the dried fish, which are often stained yellow with an infusion of turmeric, chiefly comes from the Continent. The body of the Whiting is longer for its depth than that of the Cod. The colour on the back is a dark yellowish tinge, but the sides are paler, and the belly silver-white. There is no barbel under the jaw; the vent is below the middle of



WHITING.

the first dorsal fin. There is a black spot at the axilla or root of the pectoral fin. The depth of the body is usually less than the length of the head. The upper jaw is longer than the lower jaw.

Among the other British species of *Gadus* are the *Gadus poutassou*, usually known as Couch's Whiting, which differs from the Common Whiting in its more slender shape. The Pollack (*Gadus pollachius*) has the lower jaw longer than the upper jaw. A singular instance of the pertinacity of this fish in pursuit of prey is given by Couch on the authority of Mr. Peach:—"A small Whiting was observed to have taken shelter within the cavity of a Medusa (*Cyanea aurita*), but this action was observed by a young Pollack about five inches long, which immediately began an attack. The little Whiting easily evaded the attacks by dodging round its friend, but the pursuer was soon joined

by another of its own kind. For a time both were baffled, but an unlucky movement drove the Whiting from its shelter, and a severe chase took place. Several additional Pollacks joined in the chase, like a pack of hounds, and in terror the Whiting rushed to the surface, and becoming exhausted, lay as if dead, drifting along with the tide. After a time animation returned, and the little Whiting again found refuge in the cavity of the Medusa. The movement was observed by the assembled Pollacks, which soon drove it into open water, and after a short chase it was killed by them, though they did not proceed to feed on its carcase."

The Coal-fish (*Gadus virens*) has a general resemblance to the Pollack. It is a northern fish, and especially abundant on the North American coast, and is said to range into the Mediterranean. It is met with plentifully on the coast of Cornwall, where it usually runs to a weight of twenty-five pounds, and reaches a length of about three feet. It is black on the back and dorsal fins, and lighter below. A ton and a quarter have been caught in a few hours with lines, by four men in two boats.

Species of the genus *Gadus* occur on the coasts of Kamschatka, California, in the Black Sea and Adriatic Sea, in the White Sea, and in the Polar regions. The allied genus, *Gadiculus*, which has the eye large and no teeth on the vomerine bones, is confined to the Mediterranean; and the genus *Mora*, which has only two dorsal fins, ranges from the Mediterranean to the Canaries. There are some other unimportant genera, like *Strinsia*, limited to the Mediterranean, and *Halargyreus* is found only at Madeira.

THE HAKE.*

The Hake frequents the coasts of Europe and North America, and ranges into the Mediterranean. It is one of the commoner British fishes, especially on the coasts of Cornwall and Devon. Unlike its allies, during the spawning season—January to April—it loses its appetite, and keeps near the bottom, and is then caught in the trawl-net. The night is the best time for fishing, and eleven hundred have been taken by one boat in two nights. When they gather together it is a sure sign that Pilchards or Herrings are approaching the coast. Several Hake are generally enclosed in the same seine net with the Pilchards; and Couch records that under these circumstances the Hake eats till it is utterly helpless, and he has seen seventeen Pilchards taken from the stomach of a Hake of ordinary size. The fish, however, is able voluntarily to discharge the contents of its stomach, and when caught with hook and line, at a great depth, the stomach is always found empty when it reaches the surface; and when caught near to the surface the contents of the stomach are disgorged when the animal is drawn into the boat. A large fish may weigh as much as twenty-two pounds, and its length varies from three to four feet. It is generally regarded as a coarse fish, but a good deal of the flavour depends upon the mode of cooking. Before being prepared for table, the mucus should first be removed with hot water containing some alkali. Large quantities are salted, dried, and exported to Spain, and it is stored up by English fishermen for home use when stormy weather hinders them from fishing, and for the spring season, when so many fishes retire from the coasts into deep water. The head is one-third the length of the body, but the depth of the body is less than the length of the head. The ventral fins are in advance of the pectoral fins, and the pectoral fins commence just below the hinder angle of the operculum. The first dorsal fin is short, but the second dorsal commences just over the vent, and the anal fin commences just behind it. These are both long fins, which extend down the body to near the caudal fin. The head is flattened, the lower jaw long, and the inside of the mouth and of the gill-covers black. The lateral line is white, with a black border on each side. It is straight in the hinder part of the body, but curves a little upward in front, so as to terminate above the operculum. The scales are larger than in the allied fishes. The body is of a dull brown above, and lighter on the under side. When in the best condition the colour becomes of a richer tinge. Other species of Hake are met with in the Iceland seas and on the coast of Chili.

GREATER FORK BEARD.†

The Greater Fork Beard, or Forked Hake, is a somewhat rare fish in the British Seas, but ranges round the European coasts and into the Mediterranean. It grows to a length of over two feet. It has a general resemblance to the Hake, but is placed in a different genus, because there is a

* *Merluccius vulgaris*.

† *Phycis blennoides*.

barbel under the chin, and the ventral fin is reduced to a single long ray which becomes forked at the end. In a specimen two feet long the longest part of the ventral ray measured eight inches, and the shortest five inches and a half. It is seen in the winter only, when it comes into shallow water to spawn. The body is of a lilac-grey colour, becoming pale on the belly; the fins are edged with black, except the ventrals, which have white tips. Other species of *Phycis* are found in the Mediterranean and adjacent parts of the Atlantic, and on the coasts of the United States, and at Monte Video.

The Burbot (*Lota vulgaris*) is a member of the Cod family, which is found in the fresh waters of Central and Northern Europe and the lakes of Canada, and adjacent parts of the United States. It does not occur in Scotland or Ireland, and in England is limited to the rivers of Yorkshire, Lincolnshire, Durham, Norfolk, and Cambridgeshire, but it is far commoner in Sweden and Siberia, and other cold regions of the north. In England it rarely weighs more than two to five pounds, but heavier specimens have been taken in the Trent. Scandinavian examples are referred to weighing twenty pounds. Its habits are similar to those of the Eel, for it hides itself under stones, feeds principally during the night, and sometimes hides its body in holes in the banks. The flesh is white, firm, and well flavoured, and is preferred by some epicures to that of the Eel. The length varies from one to two feet. The chin is armed with one barbel, and the upper jaw is slightly longer than the lower; the lateral line is indistinct; the ventral fins are a little in front of the pectorals and wide apart. The body has a yellowish-brown colour, clouded with darker mottlings; the under side is white. The dorsal fins and anal fin are arranged as in the Hake. This genus may be regarded as a freshwater representative of the Ling, to which it closely approximates in important characteristics.

THE LING.*

The Ling is essentially a northern fish, and ranges round the northern coasts of Europe to Iceland and Greenland. It is taken chiefly on the west coast of Britain, especially between the Scilly Isles and Land's End, all round Ireland, and among the Hebrides and Orkneys, but is also found on the Yorkshire coast. In the West of England the best captures are made in January and February; in the north of Ireland in March; and in the north of Scotland between May and August. It is caught like the Cod with both long line and hand line. It is not greatly valued for food when fresh, but salted is often preferred to Cod. The fish are split from head to tail, cleaned, soaked in brine, washed and dried, and taken to the ports of Spain. The Ling feeds readily on anything that comes in its way, and though preferring live fish, will take pieces of Herring, Pilchard, or Cuttle. Seven Plaice, six or seven inches long, have been taken from the stomach of one Ling, and another specimen had swallowed a Rough Hound. The air-bladders, or sounds, are said to be inferior to those of the Cod, but still are greatly valued when preserved. The roes—which sometimes reach a weight of eleven pounds—are also dried. The oil extracted from the liver was formerly burned in the cottages of the poor, and in more recent times, like that of the Cod, has been used in medicine. Couch has known Ling to weigh a hundred and twenty-four pounds. A specimen five feet and a half long weighed about seventy pounds, but the usual length is from three to four feet. The body is more elongated than that of the Hake. The lower jaw is the shorter, with a single barbel at its extremity. The teeth in the upper jaw are small and numerous, but in the lower jaw they are long, large, and form a single row. The caudal fin is rounded at its extremity, like that of the Burbot. The anal fin resembles the second dorsal; the first dorsal is somewhat elongated. The lateral line is straight; the colour of the back and sides is an olive-grey, or sometimes bluish. The belly is silvery; the dorsal and anal fins are edged with white, and behind the white tip of the caudal fin is a transverse black bar. Dr. Günther remarks that the bones of the skull are more solid than in the genus *Gadus*. Other species of *Molva* are found in the Mediterranean and on the coasts of Scandinavia.

THE MACKEREL MIDGE.†

Two little fishes which inhabit the North Atlantic and which only occasionally visit British seas form the genus *Couchia*. In this genus there is no air-bladder; there are barbels on the upper jaw as well as on the lower jaw, and the first dorsal fin is formed of a band of short fringes concealed in a longitudinal groove. The Mackerel Midge is one of the smallest of fishes, and

* *Molva vulgaris*.

† *Couchia glauca*.

occurs throughout the North Atlantic, being found in Chesapeake Bay, as well as in Scandinavia. It appears in multitudes about May in the English Channel, and in summer keeps near to the surface. It dies instantly on being taken out of the water. The length varies from an inch to an inch and a half. The colour of the back is sometimes nearly black, and sometimes bluish-green; the fins and belly are always silvery white. There are four barbels projecting from the flattened, obtuse head, and one from the under jaw. The second species (*Couchia argentata*) is commonly known as the Silvery Gade, which in Greenland reaches a length of three inches.

The Rocklings belong to the genus *Motella*, in which the head is no longer compressed. The small first dorsal fin consists of fringes partly concealed in a groove, much as in *Couchia*. There are fifteen or sixteen abdominal vertebrae, and thirty-two or thirty-three caudal vertebrae. The species occur on the coasts of Europe, Iceland, and Greenland. The Five-bearded Rockling (*Motella mustela*) has a barbel on the chin, with two barbels on the upper lip near the point of the nose, and two longer ones a little farther back. The body in its upper part is of a dark brown colour, but the sides become lighter, and the ventral fins and belly are white. The lateral line, which curves upward in its anterior part, is marked by intermittent white lines. It seldom exceeds a length of nine or ten inches, but has been found nearly twice as long. The species spawns in winter, and feeds on young fishes and thin-shelled Crustacea. The Three-bearded Rockling has barbels only on the upper lip; like the five-bearded species, it hides itself under stones, and does not take the hook. This species is sometimes thrown on shore in stormy weather entangled with seaweed. Its appearance has been compared to that of the Ling. Couch states that it is not used for food, because it acquires an unpleasant odour a few hours after being caught. Its length reaches seventeen inches. Two other species of the genus occur in the British Seas. One, the Four-bearded Rockling (*Motella cimbria*), has four barbels, one at each of the nostrils, a third on the middle of the snout, and the fourth on the chin. In this species the first ray of the anterior dorsal fin is greatly prolonged. The other species is the *Motella maculata*. One other species of the genus is known from Japan.

The Tadpole Hake (*Raniceps trifurcus*) is the only member of the genus *Raniceps*. It has a large broad head, and a moderately long body. There is a barb on the lower jaw. It is a wandering, solitary fish, rarely taken. Like the Rocklings, it acquires a strong odour a few hours after it has been caught. Its length seldom exceeds twelve inches. Occasionally it is brought to market with Sprats. The edge of the lip is black. The body has a darkish-brown colour, with a blue lustre, which is lost when the animal dies. Its food consists of Star-fishes, Molluscs, and Crustacea. The intestine has no pancreas. The swim-bladder is transversely divided into two parts, of which the anterior is the larger.

THE TORSK.*

The Torsk has a single dorsal fin and a narrow ventral fin, formed of five rays. The head has a single barbel; the upper jaw is the longer. The species ranges round the shores of the north of Europe and the Atlantic coast of the United States, and extends into the Polar regions. A second species, with two barbels on the chin (*Brosmus flavesceus*), is taken on the banks of Newfoundland. The Torsk is sometimes seen in the Edinburgh market, being especially abundant in the Shetland Isles, and the fishermen take it on lines set for Cod and Ling. It is described as firm and tough when eaten fresh, but much better when cured and boiled. Its length varies from eighteen inches to three feet or more. It lives on rocky bottoms overgrown with seaweeds, among which it spawns. It is plentiful on the coasts of Norway, and is often thrown up dead in immense numbers on the Færø Isles and the South of Iceland during storms.

FAMILY IV.—OPHIIDIDE.

This family comprises a group of fishes including sixteen genera, which are widely distributed in the ocean. There is only one dorsal fin in all these types. The ventral fin is very variable, being in some genera present and attached to the shoulder girdle, and in others replaced by a pair of barbels. Several genera have no ventral fin whatever, and in some of these the vent

* *Brosmus brosme*.

is brought forward so as to be under the throat. Dr. Günther divides the family into five groups of genera.

The first group, distinguished by possessing ventral fins, includes the genus *Lucifuga*, which inhabits subterranean fresh waters in Cuba. The eye is either absent or imperfectly developed, and always covered by skin. The air-bladder is remarkable for being fixed to the base of the skull. There are no appendages representing the pancreas developed at the pyloric end of the stomach. The genus *Xiphogadus* has the body naked. There is a pair of canine teeth developed at the corners of the mouth in both the upper and lower jaws. There is but one species, which is confined to the East Indies. One remarkable circumstance about this small group of fishes may be noticed in the fact that the genera are chiefly met with in the neighbourhood of islands, though one or two reach the Arctic regions, the Mediterranean Sea, and the San Francisco coast.

The second group, termed *Ophidiina*, is represented in British seas by *Ophidium barbatum*, which, though almost confined to the Mediterranean, occasionally comes to the British coast. It is plentiful in the Adriatic, and reaches a length of nine inches. Its flavour is coarse. The ventral fins are here reduced to bifid filaments, which are placed under the lower jaw in the position of barbels. There are two small bones directed downward from the first vertebra, which are connected with a large crescent-shaped bone, placed between the processes of the fourth vertebra, and this bone fits into the anterior end of the air-bladder. The air-bladder varies in its characters in the other species of the genus. In one from Brazil the anterior bone is replaced by cartilage; but it is usually absent. The body of the Bearded *Ophidium* is flesh-coloured, but the edges of the long narrow dorsal and anal fins, which meet posteriorly, are margined with black.

The third group, called *Fierasferina*, includes only two genera, both characterised by entire absence of the ventral fins, and by having the vent under the throat. The genus *Fierasfer* has the body naked, relatively long, with a tapering tail. The dorsal and anal fins extend throughout its length, and there is no separate caudal fin, for the tail tapers to a point. There are four gills. An air-bladder exists in all the species, but there are no pancreatic appendages to the intestine. Nine species are described by Dr. Günther; they are mostly found in the Malay seas, as at Ceram, Banda, Amboyna, Fiji Islands, and New Ireland. The species are mostly small. The *Fierasfer dentatus*, met with on the coast of Ireland and Scotland, which reaches a length of nearly a foot, is about the largest. It is a rare fish, and is chiefly known from the observations made on a few stray specimens. The head is small, about one-ninth of the length of the body. At each corner of both upper and lower jaws a large tooth occurs, which somewhat suggests the idea of a serpent's fang. The nostrils are very large, transverse, oval apertures, just in front of the centre of the eye. The operculum is strongly radiated. In a specimen eleven inches long the vent was one inch and three-tenths behind the extremity of the lower jaw, that is to say, immediately behind the head. There are in this species eighty-eight vertebrae. These fishes prefer sandy ground, on which they lie still for a large part of the day with the body in a curved position. Sir John Richardson describes, from Tasmania and the Australian seas, a species (*Fierasfer homi*) which has ninety-nine vertebrae, and the head relatively a little longer than in the British species. This species has the remarkable habit of penetrating into the respiratory cavities of the Holothurians, commonly called Sea Cucumbers, and it similarly finds its way into the bodies of Star-fishes, but the nature of this strange relationship between animals so unlike in their habits is at present unknown, and though the fish is probably seeking food, the instinct is so remarkable that the history of its development is looked forward to with interest. The second genus, *Encheliophis*, is distinguished by having the pectoral fins as well as the ventral fins entirely absent. The air-bladder here possesses a muscular apparatus by which its anterior part may be dilated. The species, four inches long, is found in the Philippine Islands.

The fourth group of *Ophidioid* fishes, named from its typical genus *Ammodytina*, also wants the ventral fins, but has the vent distant from the head, and consequently the anal fin is absent from the anterior part of the body. These fishes, in British seas, are known as Sand Eels and Launces. There are only two genera, *Ammodytes*, which is met with on the temperate coasts of the Atlantic, in the Mediterranean, and the shores of California, and the genus *Bleekeria*, which is only known from Madras. *Ammodytes lanceolatus* is the species commonly known in England as the Sand Eel, or

Greater Sand Eel. It sometimes reaches a length of sixteen inches, but is rarely more than a foot long. It is found around the coasts of Ireland, Scotland, and the English Channel, and on most of the shores of the North Sea. The jaws of this species have a remarkable power of expansion, so that prey can be swallowed of relatively large size. The animal swims rapidly, and is often taken in the net with Sardines and Anchovies. On the north coast of Cornwall the Launce fishery lasts from May to September. The fish are chiefly used as bait, but sometimes sold for the table. They are taken in a net about twenty fathoms long, which in the middle has a sort of bag, called a bunt, formed of fine canvas. A rope attached to one end of the net is left in charge of a man on shore. The boat is then taken out so as to spread the net in a circle and enclose the fish, when the net is drawn up into the boat. A good haul may amount to a couple of bushels, but sometimes three bushels may be taken in a single cast of the net, and it is rare for any other species to be taken with it.

The skin in this species is marked with one hundred and seventy distinct oblique folds, which are parallel to each other, and extend downward and backward, but there are no scales. The head is one-fifth the total length. The pre-maxillary bones are not capable of being protracted. There is a cartilage at the side of the lower jaw, which, according to Couch, assists the animal to pierce its way into the sand. The palate is without teeth. The back is of a bluish tinge, but the under side and dorsal and anal fins are silvery white.

The Lesser Sand Eel (*Ammodytes tobianus*) has the pre-maxillary bones protractile, and the skin of the side of the body is marked with a hundred and twenty to a hundred and thirty



LESSER SAND EEL.

transverse folds. When frightened these little fishes plunge into the soft sand of the sea-bed, working their way by means of the pointed process in which the under jaw terminates. The eggs are deposited in the galleries in which it moves as it burrows beneath the sea. Like the larger species, this is also pursued chiefly for bait. It is preyed upon by Mackerel.

The fifth group of Ophidioid fishes includes two genera, neither of which has ventral fins. The vent is far from the head in the genus *Congrogadus*. The dorsal and anal fins are continuous. In the genus *Haliophis* the caudal fin is

free. The latter genus is found only in the Red Sea, and the former ranges from Singapore to the Australian coasts.

FAMILY V.—MACRURIDÆ.

This is an important family, and includes but three genera. The body terminates in a compressed tapering tail covered with scales, which are spiny, keeled, or striated. There is one short anterior dorsal fin, and a second long one continued to the end of the tail. There are always many pyloric appendages and an air-bladder. None of the species reach British seas. *Macrurus* is chiefly characteristic of the Mediterranean, but ranges northward to Greenland, and south to the Canaries, while one species is known from Japan.

FAMILY VI.—ATELEPODIDÆ.

This family is characterised by having the long, compressed, tapering tail naked. There is only one short anterior dorsal fin, but the anal fin is very long and continuous with the caudal. The ventral fins are reduced to filaments, which are attached to the shoulder girdle. The family contains only one genus represented by a single species. *Ateleopus* has the maxillary bones protractile in a downward direction. The ventral fin internally is formed of two rays united together. The skin is naked. The species, which is marine, is known from Japan.

The first sub-order of Anacanthini consisted, as we have seen, of the Cod-like division; the second sub-order consists of the Sole-like division, the *PLEURONECTOIDEI*.

SUB-ORDER II.—PLEURONECTOIDEI.

FAMILY VII.—PLEURONECTIDÆ.

The fishes of this family are popularly termed flat fish. The body is always compressed and flat, the side which rests upon the sea-bed is usually white, but sometimes marked with spots, while the upper side is coloured usually some dull brownish tint, which more or less mimics the colour of the sea-bed on which these fishes live. The eyes, which in the embryo were originally on opposite sides of the head, come both to be placed on the upper or coloured side by the migration of one eye across the head during the development of the animal, so that the bones of the head are remarkably unsymmetrical. Almost without exception the dorsal and anal fins extend the whole length of the body, which is always broad and moderately thick. There is never any air-bladder in these fishes, which are carnivorous and naturally marine, though some of them ascend rivers. Dr. Günther describes thirty-four genera. The abdominal region of the body is remarkably small, but the roe usually extends backward between the muscles towards the tail. The vent is placed well forward, being often near the throat, and frequently between the ventral fins. In the skeleton the processes of the vertebrae in these fishes are remarkably long, but are not often much developed laterally. In swimming, all these fishes retain the horizontal position. The chief British members of the family are the Holibut, Dab, Turbot, Brill, the Carter, the Topknot, Plaice, Flounder, and Sole.

THE HOLIBUT.*

This is the largest of the flat-fish family. It is rare for a specimen more than five feet long to reach the London market, but one caught near the Isle of Man, and sent to Edinburgh, weighed three hundred and twenty pounds, and measured seven feet six inches long by three feet six inches broad, but they range to a far larger size on the shores of Iceland, Greenland, and the banks of Newfoundland, and specimens have occasionally been captured which have reached a length of twenty feet. On the coasts of Norway the fishery is carried on in spring when the nights are clear, so that the fish can be seen on the bottom. Couch states that in some localities the fishermen endeavour to transfix them with a spear, but from the powerful struggles of the fish there is always some danger of the boat being overturned. When pierced it is brought to the surface very slowly, and if possible killed with blows from a club. The species is gregarious, and occurs in the greatest numbers on the Newfoundland coast. It feeds on the smaller flat fish, and many kinds of crabs. The roe is of a pale red colour, and the eggs are deposited in spring. The body is elongated, the mouth wide, and the eyes are on the right side. The teeth in the upper jaw are in a double series, but are wanting in the palatine and vomerine bones. The scales are very small. The lateral line is curved, and the hinder rays of the dorsal and anal fins are double.

A second species, found in the Greenland seas, has the lateral line straight.

The Rough Dab, or Sand-sucker, belongs to a nearly allied genus, and is named *Hippoglossoides limandoides*. It has the lateral line straight, and the small scales have ciliated margins. The conical teeth are in a single series. The species extends along the English Channel and the shores of the north of Europe. It is a broader fish than the Holibut, with a less powerful tail; it is rare off Britain. The largest specimens seen have a length of fifteen inches. One example caught on the Cornish coast had the stomach filled with the shells of *Turritella terebra*, the greater number of which contained small hermit-crabs. The upper pectoral fin has ten or eleven rays which are never branched. The colour of the upper surface is yellowish-brown, sometimes varied with spots.

A second species occurs on the Atlantic coasts of the United States.

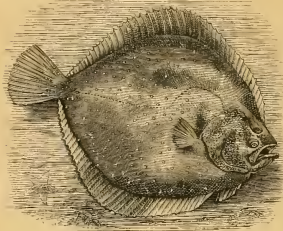
THE TURBOT.†

The Turbot is a broad fish, one and three-fifths as long as wide; it has no scales properly so called, but scattered over the surface are numerous flattened conical tubercles on the upper side. The lower eye is a little in front of the upper eye, the lateral line makes a semicircular curve above the pectoral fin. The longest rays of the dorsal fin are behind its middle, the colour varies from greyish to brownish, and the surface is sometimes covered with dark spots. The Turbot is the most valued of

* *Hippoglossus vulgaris*.

† *Rhombus maximus*.

all the flat fish, and happily is still found in great abundance. On the north-east coast of England there is a large Turbot fishery. The fishing commences in May, and on the Continental coast is largely engaged in by the Dutch. The fish migrate eastward to the mouth of the Elbe, where they are caught until the middle of August. In shallow water, and at the beginning of the season, they are taken with the trawl net, but later, when they have retired with other flat fish into deep water, they are fished for with the long line, the hooks being baited with smelt or a fish called the Gorebill. A large proportion of the Turbot supplied to the London market is caught by Dutch fishermen, and most



TURBOT.

of the Lobsters served with them in sauce are brought by Danes from the rocky coast of Norway. Good Turbot banks exist in the English Channel to the west of Dover, and along the Devonshire coast Turbot are taken by trawling. The number of Turbot brought to Billingsgate in a year is probably not far short of a hundred thousand. The Turbot is a migratory fish, travelling in companies where the bottom is sandy. It feeds chiefly on small fish, crabs, and shells, but the bait used is always some small fish of bright colour and tenacious of life, because, though voracious, the Turbot never touch bait unless it is perfectly fresh. Occasionally both sides of the Turbot are of a dark colour, and though the eyes are usually on the right side, they are sometimes found on the left side of the body. It is recorded that on one occasion the

Roman Senate was convoked to advise the Emperor Domitian as to the sort of vessel in which a monster Turbot that had been brought to him should be cooked.

On the English coasts Turbot usually weigh from five to ten pounds, though large fish range from twenty to thirty pounds, and one was taken near Plymouth which weighed seventy pounds.

An allied species (*Rhombus meoticus*) occurs in the Black Sea.

The Brill (*Rhombus levis*) is widely distributed round the coasts of Europe. It wants the firmness and delicacy of flavour of the Turbot, but is largely consumed in the London market. Its weight seldom exceeds eight pounds. Its food and habits are very similar to those of the Turbot. It is a narrower, longer fish, and there is no elongation of the fin-rays in the middle of the body. It never possesses the bony tubercles which characterise the Turbot, but in place of them has the coloured surface covered with small distinct scales.

The Whiff, Mary Sole, or Sail Fluke (*Rhombus megastoma*) in calm weather rises to the surface of the sea, and elevates its tail out of the water like a sail, when it drifts towards the land. It burrows at once into the sand, but is usually detected by a Gull, which pounces upon it, and taking out the liver with a stroke of his beak, drags the fish to some rock, where it is eaten at leisure. The Flukes are often followed into shore by Seals. It is said to be the most delicious fish of British seas, but is rarely obtained. Its length is about twenty-one inches, and breadth over the fins ten inches; the weight from three to four pounds. Dr. Günther draws no distinction between the Sail Fluke and the Mary Sole, or Carter, but Couch, not without reason, regards the Mary Sole, which is common on the English south coast, as a distinct species. The variety called the Carter has a length of eighteen inches, and a depth, exclusive of the fins, of six inches. The body is much less oblong than in the Fluke. Its colour is yellowish-brown. All the bones are thinner and more delicate in this species than in the Turbot or Brill. The ventral fins are free from the anal fin.

The Topknot (*Rhombus punctatus*) is a species met with along the English Channel, and extending to the coasts of the north of Europe. It is a comparatively small species, not exceeding six inches in length and four in width. The dorsal and anal fins extend under the tail without meeting there. The scales are very small, but there are spines upon them which make the coloured surface rough. The eyes are separated by a narrow ridge; the ventral fin is continuous with the anal fin. On the body, which is brown, are round black spots—one usually placed behind the

curve which the lateral line makes above the pectoral fin. The species frequents rocky ground, and is taken in nets set for Red Mullet. It is not an abundant fish, and is said to feed upon small starfishes and sea-shells.

Bloch's Topknot (*Pterynorhombus unimaculatus*) is a fish of very similar appearance, which has nearly all the rays which form the dorsal and anal fins branched. The scales are small and spiny, and the small ventral fin is separated from the anal fin. The first dorsal ray is generally prolonged into a filament as long as the head. The colour is brownish-grey, with black spots, and a red spot edged with black occurs on the middle of the tail. It ranges from the Mediterranean to the shores of Britain, and has been taken in the English Channel and other parts of the British coasts.

The Scald-fish, or Megrim, or Smooth Sole (*Arnoglossus laterna*), is the only representative in the British Seas of a genus which is chiefly confined to the Mediterranean, but has one species (*Arnoglossus aspilus*) occurring in Java and Sumatra. In this genus the dorsal fin commences on the snout, and the scales are shed. The British species also occurs in the Mediterranean. It is usually four or five inches long, and is rarely captured, as it never takes a bait. It is chiefly met with in the stomachs of Conger Eels, and other fishes which frequent deep water. The name Scald-fish is given from the circumstance that on being even lightly handled it readily sheds its scales as though it had been scalded. The colour is usually a reddish-yellow, with paler margins to the fin; the body has the shape of the Sole, with the dorsal and anal fins somewhat elongated, but with several of the first rays of the dorsal fin separated from each other into distinct threads.

Many allied genera have a very limited distribution. *Citharus* is confined to the Mediterranean; *Brachypleura* to New Zealand; *Samaris* to the Chinese Seas; *Psettichthys* to the western coast of North America; *Citharichthys* is found in the tropical parts of the Atlantic and the coasts of California; *Hemirhombus* is another American genus, chiefly found in the West Indies and the north coast of South America. *Pseudorhombus* is a genus with wider range, its fourteen species being spread from Africa to Australia, China, and round the Pacific, while one species is only known from New York. *Paralichthys* is Californian; *Rhomboidichthys* is a genus with many species occurring in the tropical seas, but also represented in the Mediterranean and the Sea of Japan. The Japanese form, *Rhomboidichthys grandisquama*—which ranges to the American coast—is the only species of the genus in which the scales are deciduous.

This genus *Pleuronectes*, which contains the Plaice, Dabs, and Flounder, has a narrow mouth with the teeth more numerous on the lower than on the upper side of the body. They are sometimes in single, sometimes in double series. The eyes are generally on the right side. The dorsal fin always commences above the eye; the scales are always small, and in some species are entirely wanting. The species vary so much from each other that Dr. Günther well remarks that each species would have to be formed into a separate genus if the characters which distinguish them were allowed the same importance as in the other members of this family. Some forms, for instance, have the lateral line nearly straight, in others it is strongly curved. In about fifteen species the teeth are compressed, and have a lanceolate form; in the remaining seven species the teeth are conical. Some species have minute simple scales; one has the scales imbricated. In the *Pleuronectes stellatus* and *Pleuronectes asperimus* the scales are absent, and the skin is covered with tubercles. Certain species have a prominent spine in front of the anal fin, while others want it; yet, notwithstanding these remarkable variations, the *Pleuronectes* form a natural group of fishes. They are unknown in tropical seas, and chiefly come from the Arctic regions and temperate waters, though represented in the Mediterranean by the *Pleuronectes italicus*, and in the Black Sea by *Pleuronectes luscus*.

THE PLAICE.*

The Plaice, though a soft and watery fish as commonly cooked, is in great demand among the poor of London, a special industry having grown up in the establishment of humble shops where it is cut in transverse slices, fried in dripping, and sold hot at the counters at a penny each piece. It forms an important item in the midday meal of workpeople in manufacturing districts; but by far the larger sale takes place in the evening, when the fat is carefully burned by the tradesman,

* *Pleuronectes platessa*.



PLAICE.

that its fumes may advertise his business and invite the workman to supper as he journeys home. There is a curious story told by Lacépède, which Couch quotes, concerning the common belief that Shrimps are the parents of Plaice. He states that Dr. Deslandes, having placed several Shrimps in an aquarium, found, after about twelve or thirteen days, that the vessel also contained eight or nine little Plaice. Afterwards, putting female Plaice in a vessel in which they shed their spawn, and putting in another vessel Shrimps, he obtained young Plaice only in the vessel which contained the Shrimps. He then found that grains of the roe of the Plaice were attached to the under-side of these crustacea. This case is probably exceptional. It is well known that the eggs of all fishes, when shed, are contained in a glutinous covering, by which they become attached, and it would seem that the Shrimps, which feed on fish-eggs, sometimes get them adherent to their own bodies, and thus carry them about till they are hatched. Plaice have been caught weighing fifteen pounds; a specimen has been mentioned two feet long. The general size is about three pounds, and seven or eight pounds is an unusual weight. Yarrell states that on one occasion the glut of Plaice in Billingsgate market was so great that quantities of fish averaging three pounds each were sold at a penny a dozen, and one salesman, who possessed a hundred bushels, offered them at fifty for fourpence, and afterwards for anything he could get. As it was impossible to sell them, they were divided among the poor by direction of the Lord Mayor. Fishermen can generally detect, from the appearance of the fish, the locality from which it is taken. The species inhabits sandy banks, and sometimes occurs on mud banks. On the flat sands of the Solway Firth the fishermen and their families wade into the water with bare feet; when they tread on a fish it is held firmly till secured by the hand and placed in a basket. In the North of Europe, according to Yarrell, where the water is clear and the bottom rocky, it is captured, with a heavy short spear with two barbs, to which a line is attached, which is dropped upon the fish from a boat so as to transfix it. In East Friesland the Plaice thrives well in fresh-water ponds in which it has been introduced. Plaice spawn in the early spring, and are considered to be in the best condition by the end of May. They are sometimes taken with the line and sometimes with the trawl. The height of the body is about one-half the length, exclusive of the tail; the scales are minute and smooth; six blunt bony tubercles extend from the eye to the origin of the lateral line. The lateral line curves a little above the pectoral fin; the lower jaw is prominent. The upper jaw has about twenty-four narrow teeth close set on the lower side. On the upper side the teeth are few and small. The dorsal fin contains about seventy rays. There is a spine in front of the anal fin. The colour varies from brown to black with yellow spots.

THE DAB, OR SALTIE, OR SALT-WATER FLUKE.*

The Dab is met with all round the coasts of Britain, and ranges northward to Ireland, and round the northern coasts of Europe, but does not reach farther south than the coast of France. It is rarely more than a foot long, has an oval form, is met with in smooth, sandy bays, and feeds on small shell-fish, worms, and crustacea, and is in best condition in March or April. It bears carriage well, so that it is valued in the interior of France above similar fishes, and there is no doubt that its flavour is better than that of the Plaice or Flounder. It often takes the hook, but is sometimes caught in the seine net and sometimes in the trawl. The height of the body is nearly one-half its length; the small scales have the margin ciliated; there are no tubercles along the lateral line or at the base of the fins. The lateral line forms a semicircular arch above the pectoral fin, beyond which it runs straight. There are twenty-two close-set lanceolate teeth on the lower side of the lower jaw.

The Smear Dab (*Pleuronectes microcephalus*) is called by Yarrell the Lemon Dab, or Smooth Dab. It is a larger and thicker fish than the Common Dab, and is taken in the North of Scotland more abundantly than southward, and is essentially a northern fish, ranging to Iceland and the Scandinavian coast. It spawns in May and June, feeds on similar animals to the Common Dab, but is said also to feed on Chitons. It does not readily take a bait, and is usually caught in the trawl; its flesh is said to be sweet-flavoured. Couch records specimens seventeen inches long. The scales are small, with the margins unbroken. The lateral line has a very slight curvature above the pectoral fin. There is no prominent spine in front of the anal fin. There are sometimes darker marblings on the brownish upper surface.

* *Pleuronectes tinanda*.

The Pole, or Craig Fluke (*Pleuronectes cynoglossus*), is another Arctic species which frequents British coasts occasionally, and is sometimes met with on the coast of Belgium. It has been captured somewhat plentifully with the net near Newcastle, in County Down. The stomachs contain bivalve shell-fish and crustaceans. They reach a length of sixteen or seventeen inches, a breadth of eight or nine, and a thickness of one inch. The shape is very similar to that of the Sole. The lateral line is straight, without any curve above the pectoral fin. The small scales entirely cover the head, on which they become imbricated. There is no prominent spine in front of the anal fin. The colour is greyish-brown.

THE FLOUNDER.*

The Flounder abounds on all the British coasts, and extends from France round the northern shores of Europe to Iceland and Greenland. It is common throughout the Baltic as far north as lat. 60°. Couch mentions that it is largely preyed upon by many sea birds, especially the Divers, Cormorants, and the Sbag. Being unable to swallow so wide a fish, it is first pecked so as to break the bones, and then the sides are rolled together, and the fish is passed head foremost into the bird's gullet. A length of a foot is a large size; the females are probably a little larger than the males. The roe attains its full size in December, and the young appear about the beginning of the following May. The eggs are deposited at the mouths of rivers. The colour of the animal mimics that of the sea-bed on which it lives. Yarrell records that the backwaters behind Yarmouth yield dark-coloured fish, while those caught in the sands at sea have a light colour. The Flounder thrives well in the Thames, and is taken at Teddington and Sunbury. In France it occurs as far inland as the Dordogne. From Deptford to Richmond the Thames fishermen use a tuck net for its capture. One end of the net is fixed by an anchor, and its position marked by a buoy; the boat is then sculled by an apprentice in a circle while the fisherman pays out the net from the stern. When the circle is complete the net is hauled in across the fixed end. In the Avon Flounders ascend within three miles of Bath, and they live well in fresh-water ponds. Occasionally both sides are colourless; or both sides may be coloured, or the colour may vary through many shades of brown; yellowish spots sometimes occur on the sides, and, according to Blanchard, are most vivid in the spring, and disappear later in the year. The body resembles that of the Plaice in form; the teeth are obtuse and conical; the scales are minute and smooth, but there are bands of rough scales or tubercles on the side of the head; rows of rough tubercles extend along the bases of the dorsal and anal fins; the lateral line curves very slightly above the pectoral fin. In Normandy it is used, according to Blanchard, in the process of washing wool imported from America.

THE SOLE.†

There are thirty-three species of Sole, widely distributed through tropical and temperate seas; several are limited to the West Indies, others extend from the Australian coasts by way of the Malay Islands to the China Seas and Japan. A fresh-water Sole (*Solea mentalis*), seven inches long, is only known from the river Capin, in the province of Para, in Brazil. There are four British species of Sole, and one of these (*Solea minuta*) is not known from any other locality. The chief variations which species exhibit are in the presence or absence of one or both of the pectoral fins, some Japanese species wanting both fins. The constant characters are the oblong body, rounded in front; the narrow mouths, obliquely twisted to the left side, with fine teeth in bands on its blind side only. The lateral line is straight, the scales are small and ctenoid, and the dorsal fin is not blended with the tail.

The Common Sole delights in sandy and gravelly places, and abounds all round England in deeper water than the Flounder or Plaice. It ranges into the Baltic and throughout the Mediterranean. Yarrell quotes Dr. McCulloch as stating that in Guernsey a Sole had been kept in a fresh-water pond in a garden for many years, and became twice as thick as a Sole from the sea of the same size. Soles breed freely in the river Arun, near the town of Arundel, which is five miles from its mouth, remain in the river throughout the year, and bury themselves in the sand during the cold months of winter. Here they are often taken of a pound weight, sometimes weighing two pounds, and are always relatively thicker than sea Soles. Soles especially abound along the English

* *Pleuronectes flesus*.

† *Solea vulgaris*.

Channel between Devonshire and Sussex. The largest specimen known was caught off Totnes, and was twenty-six inches long and eleven inches and a half wide, and weighed nine pounds.

Soles feed at night, and hence are not often taken with the line, since that kind of fishing is chiefly carried on by day. When they are caught with the line worms are used as bait. The Sole spawns in the spring; and though out of condition while depositing the eggs, recovers in a few weeks. The flesh is remarkably firm, white, and well flavoured, and the variety of ways in which it is cooked is an evidence of the esteem in which it is held as one of the best of British fishes. The height of the body is contained twice and five-sixths in the total length. The colour is dark brown.

The Lemon Sole (*Solea aurantiaca*) is distinguished by its yellowish or lemon colour, marbled with brown and speckled with black, and there is a remarkable large black spot on its hinder half. It is rather wider in proportion to its length than the Common Sole, has a smaller head, and is rather thicker; the under side of the head is nearly smooth, and the nostril there projects in a little tube. The upper jaw projects beyond the lower jaw, but its extremity is rounded. It attains a length of eight or nine inches, and is taken on the shores of Ireland and in the British Channel, but ranges southward as far as Portugal.

The Variegated Sole (*Solea variegata*) is rarely more than eight or nine inches long, and closely resembles the Common Sole. The pectoral fins, however, on both sides are extremely small. The colour is brownish-grey, with dark irregular bands extending between the dorsal and anal fins. It is thick in the body. It is plentiful at Plymouth, is met with in the stomachs of fishes caught at a depth of forty or fifty fathoms, is excellent eating, and has been taken in the Mediterranean.

The Solenette (*Solea minuta*) attains a length of five inches; it has a reddish-brown colour. The pectoral fins are rudimentary, and the lower half of the right pectoral is black. It is often found in the stomachs of larger fishes, and is taken freely with the trawl in Cornwall and Devonshire, but from its small size does not often come to market.

All these fishes, like many others which live naturally either upon or near to the ground, are captured with the trawl. This is a net in the form of a bag, which is trailed from the boat. It is usually of a triangular shape, and is so made that the mouth of the net is kept always open. The simple trawl, with the mouth distended by ropes extending from the netting to poles projecting from the sides of the vessel, is still used in the fisheries of some parts of Ireland. The favourite form of trawl is that called the beam-trawl, in which the mouth of the net is extended by a horizontal wooden beam which is raised a little above the ground by two iron supports, one placed at each side. In the large smacks the beam may be from thirty to fifty feet in length. The timber is usually elm, ash, or beech. It is considered important that the wood should have grown naturally to the proper thickness and length, though sometimes several pieces are fitted together and secured by binding. At ordinary times the beam is carried hoisted up at the side of the vessel, with one end made fast to the stern. The head irons, as they are called, carry in the top the beam, to the back of which the net is fastened. In front the rope is attached by which the trawl is hauled along, but the head irons to which it is made fast vary in shape and weight on different coasts and in different countries. The weight of the two irons as a rule varies between 230 lbs. and 360 lbs., and depends chiefly on the force of the tides in the district which is fished. These irons keep the beam nearly three feet above the ground. The net has been compared to an old-fashioned bed watch-pocket laid on its face. Care is taken to have the ground rope, which extends in front of the net round its curved outline, made of old material, so that it may break in case it should become entangled among jutting rocks or other obstacles on the bottom. The net tapers towards its hinder extremity, which is called the cod-end, and as the fish usually press upon this end when the net is full it is protected by pieces of old netting, which are named rubbing-pieces. At the entrance to the narrow part called the cod, the back and belly of the net are laced together from the outer edge inward and backward, so as to narrow the entrance through which the fish pass inward, and to form pockets at the sides in which they can swim. The entrance between the pockets is guarded by a veil of netting which hangs downward from the back of the net. This is called the flapper; fish pass under it easily, but do not readily make their way back again. The pockets are chiefly useful by taking the pressure off the sides of the net, so that the Sole, which loves quiet, naturally makes its way into the pocket, and thus, by distributing the weight over a larger space,

the pocket enables the fish to escape crushing from stones which may find their way into the trawl. The net is twice the length of the beam, but is open below for the first half of its length. The pockets are about half the length of the beam, and the cod about half the length of the pockets. The trawls are usually kept down continuously for five or six hours.

The trawl is usually towed in the same direction as the tide is running, and does not move much faster than the progress of the tide. It requires some skill and technical appliances in lowering it, so that it should reach the ground the right way up. The fish lie with their heads to the tide, close together, and when disturbed by the ground rope of the net they pass over this obstruction without difficulty into the net. When the tide is done, or the boat has reached the limits of the fishing ground, the vessel swings round with her head to the trawl, the rope is hauled in by the men at the winch, and coiled away till the beam comes to the surface. The beam is then hauled over the gunwale and made fast, and the net is got in by hand. If the catch is a good one, bringing up from half to three-quarters of a ton of fish, the winch is used to hoist up the cod on to the deck, where the fish are emptied out. Trawl fishing is much more successful at night, because the fishes feed at night, and there is more trawling in winter than in summer, because there is then more wind. In the North Sea the fishing smacks often remain for six weeks or two months with the fleet at long distances from land. Most trawling is done in a depth of from twenty to thirty fathoms. In cold weather the Soles especially pass into deeper water, and then the fishing may extend to forty fathoms or more.

CHAPTER IV.

THE ORDERS PHARYNGOGNATHI AND ACANTHOPTERYGII.

Characters of the Order PHARYNGOGNATHI—THE POMACENTRIDÆ—Distribution—Diet—Distinctive Features—THE LABRIDÆ—Characters—The Ballan Wrasse—The Cook Wrasse—The Corkwing—Other Genera—The Group *Chæropina*—The Group *Julidina*—The Rainbow Wrasse—The Genus *Pseudodax*—The Group *Scarina*—The Group *Odicina*—THE EMBIOTOCIDÆ—THE GERRIDÆ—THE CHROMIDÆ—THE ORDER ACANTHOPTERYGII—Dr. Günther's Classification—THE PERCIDÆ—THE PERCH—Where Found—Diet—Large-sized Specimens—Characters—THE BASS—THE RUFFE—Allied Genera—The Smooth Serranus—The Dusky Perch—The Stone Bass, or Wreck-fish—Why so Called—THE PRISTIGOMATIDÆ—THE SQAMIPINNÆ—Characters—Various Genera—Curious Habit of Shooting at Insects—THE NANDIDÆ—THE MULLIDÆ—THE RED MULLET—Epicurean Luxury—Mode of Cooking—THE SPARIDÆ—THE BLACK SEA BREAM, or OLD WIFE—The Bogue—The Common Sea Bream—The Gilt-head—THE HOPOGNATHIDÆ—THE CIRRHITIDÆ—SCORPENINÆ—THE POLYCENTRIDÆ—THE TEUTHIDIDÆ—THE BERYCIDÆ—THE KURTIDÆ—THE POLYNEMIDÆ—THE SCLENIDÆ—The Maigre—Value of its Head—THE XIPHIIDÆ—The Common Sword-fish—Contests between Fox Sharks, Sword-fishes, and Whale—The "Sword"—THE TRICHIURIDÆ—The Scabbard-fish—The Silvery Hairtail—THE ACRONURIDÆ—THE CARANGIDÆ—The Scad, or Horse Mackerel—THE CITTINÆ—The John Dory—Characters—Whately's Little Joke—Legends about the Dory—THE STROMATEINÆ—THE CORYPHENINÆ—The Ray's Bream—The Opah—THE NOMEINÆ—THE SCOMBRINÆ—THE MACKEREL—Young "Shiners"—Size—Abundance—Migrations—Voracity—Mackerel-fishing—The Spanish Mackerel—The Tunny—Characters—Size—The Tunny Harvest—Beef-like Flesh—The Bonito—The Germon—The Genus *Pelamys*—The Genus *Auxis*—The Pilot-fish—THE SUCKING-FISH, or REMORA—Nature of the Sucking Disc.

ORDER IV.—PHARYNGOGNATHI, OR FISHES WITH JAWS IN THE THROAT.

THE order of fishes termed Pharyngognathi is so named from the circumstance that they have lower bones in the gullet, termed pharyngeal bones, which are blended together, though there is frequently a median suture between them. The air-bladder in these fishes is not connected with the throat by a pneumatic duct. The order is moreover distinguished by some of the rays of the dorsal, anal, and ventral fins forming spines, and showing no indication of the usual jointed structure. Dr. Günther follows Müller in his definition of the order, but divides it into five families, named from typical genera—Pomacentridæ, in which the scales are ctenoid; Labridæ, in which the scales are cycloid; Embiotocidæ, which have numerous rays in the anal fin; the Gerridæ, which have few rays in the anal fin; and the Chromidæ, which entirely want the pseudo-branchiæ, or gill on the operculum.

FAMILY I.—POMACENTRIDÆ.

This family includes eight genera, distinguished by having twelve vertebrae in the abdomen and fourteen in the tail. They abound chiefly in the Indian and Pacific Oceans. Some extend as far as the south coast of Australia and to the Pacific shores of America. A few reach northward to Japan, and some are found in the Mediterranean. Their food varies with the locality; in the neighbourhood of coral reefs it consists chiefly of marine plants and the various small zoophytes which there flourish, but almost all small marine animals contribute to their ordinary diet. These fishes have a compressed and somewhat short body, the lateral line on which does not extend to the caudal fin. There is one dorsal fin with the spiny part well developed. The anal fin has two or three spines, the remainder being soft like the dorsal. The ventral fins are placed in the thoracic region. The intestine, which is moderately long, has a few pyloric appendages behind the stomach. The different genera are distinguished by the form and arrangement of the teeth, and the presence or absence of serrations on the opercular bones. Many of these fishes are remarkable for the variety of their colours: thus, *Amphiprion* has a black or brown ground colour, with white or pearly cross-bands, while some of the fins are often of a bright yellow. In the allied genus, *Dascyllus*, the cross-bands, when they exist, are usually black on a yellow ground, but sometimes the body is green and the tail blue. In *Glyphidodon* the cross-bands are indifferently light and dark, and the colour of the body varies, and in several genera the scales often have a dot of different colour from that which pervades the back and body.

FAMILY II.—LABRIDÆ.

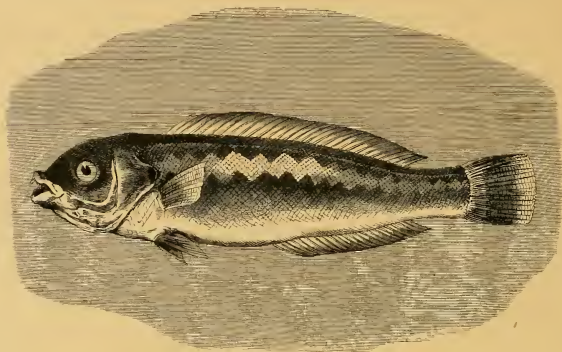
The Labroid family comprises a vast number of marine fishes, which are met with in temperate or tropical waters. They are unknown in the Arctic and Antarctic Seas. They feed chiefly on mollusca, and the dentition on the single lower pharyngeal bone is well suited for crushing shells. Many species have a strong curved tooth at the hinder end of the pre-maxillary bone, which presses a shell against the lateral and front teeth, by which it is crushed. The body is covered with cycloid scales; the lateral line does not always reach to the caudal fin. There are no pyloric appendages to the stomach. In this family Dr. Günther arranges forty-six genera, which are classed, according to the characters of the teeth, fins, and scales, into six groups. The genus *Labrus* is found on the coasts of the temperate parts of Europe and off the northern shores of Africa. There is a peculiarity in the skeleton in this type, in that the basi-occipital bone has on each side a large surface like a flattened condyle, which fits into concavities in the upper pharyngeal bones. The teeth in the jaws are conical, and ranged in a single series. This genus includes many of the Wrasse.

The BALLAN WRASSE (*Labrus maculatus*) is perhaps the best known. It is found sheltered among seaweeds in deep holes among the rocks. It spawns in spring and summer, when the colours become most brilliant. It is said to feed chiefly on crustacea and marine worms. A large specimen may reach a length of eighteen inches, but on the Irish coasts they grow to a much larger size. The back is often red and the belly orange, while the body is ornamented with bluish-green spots. All the scales are margined with colour. The pectoral and ventral fins are orange-red, but the vertical fins are usually bluish-green. This species has a wide distribution on the European coasts, through the Mediterranean, and on the north-west of Africa. The young of the Ballan Wrasse has the pre-operculum well serrated, and has been regarded by some writers as a distinct species.

Another well-known species is the COOK WRASSE (*Labrus mixtus*). This species, which is also known by many popular names, such as the Red Wrasse, Striped Wrasse, and Spotted Wrasse, is remarkable for the great difference of appearance which distinguishes the sexes. The male has the body of a dark greenish tint above, becoming yellower on the body, and is marked with blue stripes running the length of the body. The female, on the other hand, is red, with two or three large black spots or blotches across the back of the tail. The young males are said greatly to resemble the females. Like the other species of its genus, it is found chiefly among rocks and the larger seaweeds, feeding on crustacea. During the summer these fishes come into shallow water, but in the autumn they retire again to a deeper part of the sea. The males may

reach a length of fourteen inches, but the females are rarely more than a foot long. The female in the Mediterranean is said to breed twice in the year. It is common in the North Atlantic, but more abundant on the southern shore of England than farther eastward. It does not enter the Baltic, and has not been met with in Iceland or Finmark.

The CORKWING (*Crenilabrus melops*) is a Wrasse which ranges round the coasts of Europe. There is a brown or black spot behind the eye, the sides of the head are red, the back has a purplish tinge, and the under side is greenish. The body is marked with longitudinal stripes, which have a violet colour in the upper part, but become red lower down. The dorsal, anal, and ventral fins are green, and the pectoral fins reddish-yellow. This species has a deeper body than any other British Labroid fish. The scales number thirty-seven on the lateral line, above which are four rows of scales, and there are ten rows below it. In this genus the pre-operculum is denticulated, as in the young of the



RAINBOW WRASSE.

genus Labrus. All the species have imbricated scales on the cheeks and on the opercular bones. The conical teeth in the jaws are arranged in a single series.

The other species are all confined to the Mediterranean, the Black Sea, and the neighbourhood of Madeira.

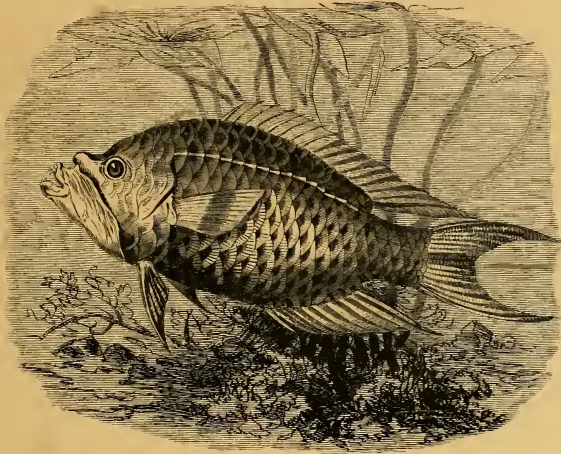
Lachnolaimus is a genus confined to the Caribbean Sea. The genus *Tautoga* is a black fish from the Atlantic coasts of the Northern States of North America. *Malacopecterus* is another genus from the island of Juan Fernandez; *Ctenolabrus* is a genus found in the Mediterranean and temperate parts of the North Atlantic, represented in English seas by *Ctenolabrus rupestris*. The genus *Acantholabrus* is represented on the coast of Cornwall by a species named in honour of Mr. Couch. *Centrolabrus* ranges from the Canary Isles to Greenland, is known on the English coast from one species, the *Centrolabrus exoletus*, and is distinguished by the small size of its mouth. The fish is seldom more than four inches long. There are sixteen rows of scales on each side, and thirty-two scales on the lateral line.

The second group of Labroid fishes has been named *Cheropina*. It includes only the one genus *Cherops*, which is found in the Indian and Australian Seas, and has a species ranging to China and Japan.

The third group, named *Julidina*, includes thirty-seven genera, distinguished by having, as a rule, fewer than thirteen spines in the dorsal fin, and frequently, in some groups of genera, only

eight or nine spines. These fishes are widely distributed in the Indian Ocean, in the Caribbean Sea, and Pacific coasts of North America, and a few range to China and Japan; but the only British representative of the group is a species of the widely-distributed genus *Coris*—the *Coris julis*—which has a small black spot just over the origin of the pectoral fin, a blue spot on the extremity of the operculum, and a violet spot between the three or four anterior dorsal spines. This species is commonly known as the Rainbow Wrasse. It is frequently met with in the Mediterranean and at the Canary Isles. Its most northern limit is the south coast of England. There are many varieties, distinguished by red or white lateral bands. In the genus *Epibulus* the lateral line is interrupted, and the cheeks and opercular bones are covered with large scales. The species here figured comes from the Indian Archipelago, and is the only member of the genus.

The fourth group includes but one genus—*Pseudodax*—which frequents the seas between Java



EPIBULUS INSIDIATOR.

and the Celebes, and is distinguished by having each jaw armed with two pairs of broad incisors with a cutting lateral edge, and the teeth on the lower pharyngeal bones are said by Dr. Günther to be confluent.

The fifth group, including five genera, is named from the type genus *Scarus*—*Scarina*. These fishes are confined to the tropical seas, and chiefly known from the labours of Dr. Bleeker. They have the teeth in both jaws blended together so as to form broad convex cutting edges. Here, also, the pharyngeal teeth form a pavement.

The sixth and last group of the Labroid family, named from the genus *Odax*—*Odacina*—includes four genera. The edge of each jaw is sharp and cutting, without the teeth being distinct in front, the scales are small, and the snout is pointed.

FAMILY III.—EMBIOTOCIDÆ.

This family includes two genera—*Ditrema*, which has seven to eleven dorsal spines, and is represented by many species, and *Hysteroecarpus*, known from one species. Both genera ascend

some of the Californian rivers. These fishes are viviparous; they have a large simple air-bladder, and the stomach is destitute of pyloric appendages.

FAMILY IV.—GERRIDÆ.

The Gerridæ comprise the one genus *Gerres*, represented by many species in tropical seas. These fishes are oviparous; they have rudimentary pyloric appendages. There is always an air-bladder.

FAMILY V.—CHROMIDÆ.

The fifth and last family is the Chromidæ, a large group of nineteen genera, distinguished by their teeth, spines, and scales. They are fresh-water fishes, which are chiefly met with in the tropics. One genus, *Etrophus*, occurs in Western India. The herbivorous species have the intestines convoluted and the teeth lobed; but there are carnivorous species, with simple pointed or conical teeth. *Chromis galileus* is from the Sea of Galilee. *Chromis*, *Sarotherodon*, and *Hemichromis* are African genera; the others are all American.

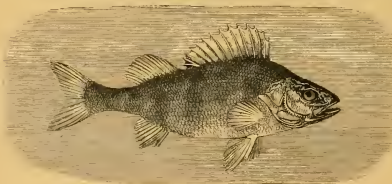
ORDER V.—ACANTHOPTERYGII, OR SPINY-FINNED FISHES.

The Acanthopterygii comprise a vast multitude of fishes, among which are some familiar fresh-water forms which occur in the rivers of Great Britain. All these genera are characterised by having the inferior pharyngeal bones separated from each other, and by having some of the rays of the dorsal, anal, and ventral fins developed into spines, and therefore wanting in the jointed character which is seen in the remainder of the fin rays. The air-bladder is sometimes absent and sometimes present, but it never possesses an air-duct to connect it with the throat. In the following pages the genera are arranged according to the system developed by Dr. Günther. In his arrangement of the fishes in the British Museum, five principal subdivisions of the order are adopted; the first of which includes sixteen out of the twenty groups of families, or smaller natural divisions of the order. The first section of the order, comprising the sixteen divisions, is distinguished by having a soft dorsal fin and an anal fin. The vent is always distant from the extremity of the tail, and is placed behind the ventral fins whenever they exist. The first division of this great group, termed Perciformes, comprises eleven families, in which the dorsal fin or fins occupy the greater part of the back; and the soft anal fin is similar to the soft dorsal. The ventral fins are placed under the throat; they have one spine and four or five well-developed rays.

FAMILY I.—PERCIDÆ.

The type of the Perciform division is the Perch, best known from the *Perca fluviatilis*, which is widely distributed throughout the temperate parts of Europe and Russia in Asia, where

it is confined to fresh waters. Two other species are known, both of which are found only in Canada and North America. The Perch is said to be wanting in the more northern counties of Scotland, though it inhabits Scandinavia up to the 69° parallel of latitude. These fishes feed on insects, worms, and many small fishes. The eggs are deposited in long strings during spring, and number more than a quarter

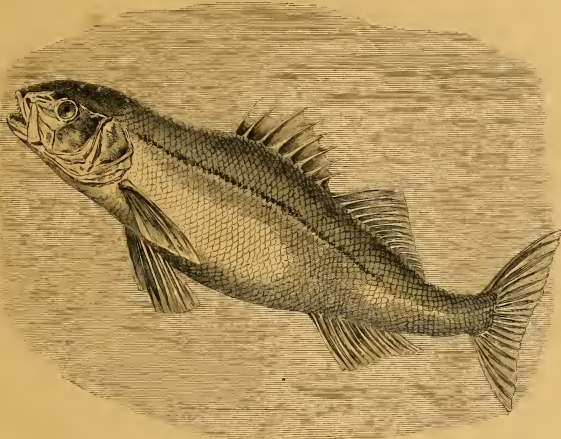


RIVER PERCH.

of a million in a single fish. Yarrell observes that they live so well out of water that they are constantly to be seen alive in the markets of Southern Germany, from which they are taken back again, if unsold, to the ponds from which they were brought. Occasionally this species reaches a large size. One weighing nine pounds is said to have been caught in the Serpentine in Hyde Park; and Yarrell quotes Schäffer as stating that the head of a Perch, which measures nearly a foot in length, is preserved in the Church of Lulea, in Lapland. English specimens

have not measured more than twenty-nine inches in total length. In Lapland the skins of the Perch are boiled in a bladder, so as to form a kind of glue. The head is two-sevenths of the length of the body; the teeth are small, and directed backward. There are also teeth on the palatine bones. The upper part of the body is of a warm greenish-brown tint, becoming golden at the sides and white on the belly. There are always broad dark bands of colour passing vertically down the sides. In summer the Perch prefers the rapid parts of the stream, but in winter the fish retire to deeper and quieter pools, where they herd together in large numbers.

The genus *Percichthys* is confined to the fresh waters of tropical America and Java. *Paralabrax* is a genus limited to the rivers of California. *Labrax* has some species living in the rivers and shores of North America, but is best known from the European species called the Bass



FASSE.

(*Labrax lupus*), which is a marine Perch, having teeth on the tongue and only nine spines on the first dorsal fin. There are scales on the gill-covers, as was pointed out by Aristotle. The species is gregarious, and enters the mouths of rivers in autumn to deposit the spawn. The individuals feed on various small fishes, such as young Whiting and the Sand Launce, and eat Shrimps and other small Crustacea. They are more abundant on the south coasts of England and Ireland than farther north, and range to France, Portugal, and the Mediterranean.

Another fresh-water fish met with in the rivers of Europe, and closely resembling the Perch in its habits, is the *Acerina cernua*, commonly known in England as the RUFFE, a name said to be derived from the harsh sensation given by its ctenoid scales. It is of an olive-green colour, marbled and spotted with brown. Many genera of this family are limited in their range. *Percarina* is found only in the Dniester, *Pileoma* in the lakes and rivers of North America, *Nippon* is a genus met with in the Japanese Sea, and *Euplosus* occurs in the Australian seas.

Another section of the Perch family has for its type the genus *Serranus*, which genus alone comprises more than 130 species. It is represented in English seas by the *Serranus cabrilla*, or

SMOOTH SERRANUS, and the DUSKY PERCH (*Serranus gigas*). In this genus both jaws have very distinct canine teeth. The Dusky Perch is met with on the coasts of France and Spain, and in the Mediterranean, where it sometimes reaches a weight of sixty pounds, though in the Indian Ocean its size becomes enormous. In British seas they vary from ten to twenty pounds. The colour of the back is a dark reddish-brown, becoming paler on the belly. The Smooth Serranus also abounds in the Mediterranean, and reaches southward to Madeira. This fish has sometimes been believed to be hermaphrodite, one lobe of the roe consisting of ova and the other lobe consisting of milt; but this view, though sanctioned by Cuvier, is probably an error, due to some peculiarities in its reproductive apparatus.

Pleuropoma is a genus limited to the tropical seas of both hemispheres. In English seas the Stone Bass (*Polyprion cernium*) is met with. The species ranges southward to Madeira and the Mediterranean. It has sometimes been called the Wreck-fish, from the circumstance that it often comes in with fragments of wreck, which are covered with the goose-barnacle. Couch remarks that they gambol round these floating objects, and he has known their tails to be excoriated by rubbing against the wreckage. They do not feed on the barnacles. As many as thirty-five have been taken by a single boat round one piece of wreck. The fish is about eighteen inches long, and is valued for table.

FAMILY II.—PRISTIPOMATIDÆ.

This is a large family, and is distinguished from the Percide by having the palate toothless. In one or two genera there are no teeth, but usually minute teeth are arranged in bands, and in some genera they are pointed and conical. The air-bladder is usually undivided. They are carnivorous fishes, found in the seas of temperate and tropical regions; a few occur in fresh waters. In British seas the group has but two representatives—*Dentex vulgaris* and *Mæna vulgaris*. *Dentex* is a widely-distributed genus, met with in the Mediterranean, Atlantic, Red Sea, Sunda Sea, and the Sea of Japan. It always has strong canines in both jaws. There are only six branchiostegal rays; the dorsal fin is continuous. There is a notch at the posterior end of the swim-bladder. The British species is a rare visitor on English coasts, and is more at home in the Mediterranean and about the Canary Islands. It carries four canine teeth in each of the jaws, the outer pair stronger than the inner pair. The fourth dorsal spine is the longest. The colour is silvery-blue, with some irregular black spots on the back. *Mæna vulgaris* scarcely extends beyond the Mediterranean, and in British waters has only once been met with on the Cornish coasts.

FAMILY III.—SQUAMIPINNÆ.

The Squamipinnæ comprise twelve genera, arranged in three divisions, according to the presence or absence of teeth on the palate and the position of the dorsal fin on the back. This is a group of carnivorous fishes, especially abounding in the Indian region and other seas between the tropics, though a few genera have a wider range, and enter rivers. The intestine is generally convoluted; the stomach forms a pouch, and has a few pyloric appendages. The vertical fins are more or less covered with scales, the eyes are placed laterally, and the teeth are like short bristles. The body is compressed and remarkably deep, and frequently marked with black and white spots and transverse or oblique bands, the colours of which are extremely brilliant. Swainson observes that the Chaetodonts are the most beautiful of the whole class of fishes. None of them are large, and all are said to be nutritious and savoury food. Among the genera of this family, *Chelmo* has the muzzle elongated into a cylindrical tube, with a small cleft in front for the mouth. There are no teeth on the palate; and there is no spine on the pre-operculum. The body is greatly compressed from side to side, and is deep. *Chelmo rostratus* has five vertical brown cross-bands, which are bordered with white and brown. A round black spot bordered with white occurs in the middle of the soft part of the dorsal fin. This species sometimes ascends rivers, but is chiefly found in the Polynesian seas between India and the West Coast of Australia. *Heniochus* is distinguished by having the fourth spine of the dorsal fin prolonged into a delicate whip-like process. *Holacanthus* has a long strong spine developed from the posterior angle of the pre-operculum, and a similar spine is seen in *Pomacanthus*. *Ephippus* has the colour uniform in the adult. *Atypus* and *Scorpius* are two genera which are almost limited to the Australian seas; both these types have the dorsal fin



TOXOTES.

in the middle of the back. *Atypus* feeds on vegetable as well as animal substances. The genus *Toxotes* has the dorsal fin, which contains only five spines, placed on the posterior half of the back.

Many of these fishes possess the remarkable habit of shooting at insects observed upon plants which overhang the water or fly above it, by forcibly ejecting water from the mouth, a circumstance remarked upon by Swainson as being altogether unique as a hunting habit and mode of capturing prey.

FAMILY IV.—NANDIDÆ.

The Nandidæ are a small family, including about six genera of tropical fishes, which are all carnivorous. The body is compressed and oblong, and, unlike all the foregoing three families, has the lateral line interrupted. The ventral fins are placed under the thorax. The pseudo-branchiæ, which occur in the marine genera from the Red Sea and the Pacific, are absent in the fresh-water genera of the East Indies, and hidden in the genus *Acharnes*, which is met with in the fresh waters of British Guiana.

FAMILY V.—MULLIDÆ.

The Mullidæ are distinguished by having a pair of long movable barbels on the throat attached to the hyoid apparatus. There are four branchiostegal rays and two dorsal fins, which are distant from each other. The profile of the head is always a convex curve, and the elongated body is covered with large scales. There are five genera of these Mulletts, which chiefly inhabit tropical seas, though the genus *Mullus*, which includes only two species, is limited to the Mediterranean and the temperate coasts of Europe. The Australian genus, *Upeneichthys*, makes its way up rivers. Both the Red Mulletts occur on British coasts. The *Mullus barbatus* is rare, and met with only occasionally on the coasts of Berwickshire and Cornwall, though it is abundant in the Mediterranean. Its colour is duller than that of the Red Mullet, and varies between red and olive-yellow.

THE RED MULLET.*

This fish is also called the Striped Surmullet, from the circumstance that its bright red colour is relieved by three longitudinal stripes of yellow. The flesh of this fish is white, firm, and remarkably free from fat, and has always been esteemed one of the epicure's greatest luxuries. Its flavour improves with the size, and small fish deprived of the liver are more or less insipid. The method of cooking by rolling them in paper to prevent injury to the skin has been observed for at least two thousand years. Among the Romans Mullet of moderate size were worth their weight in silver. In Great Britain they do not usually exceed three pounds and a half in weight. Couch mentions one which was sixteen inches long. After death the colours fade. The species is migratory, but most abundant in the English Channel. They are often caught in Mackerel-nets, near to the surface, but more frequently in the trawl-net. Occasionally they are so abundant that five thousand have been taken in a single night. Their rarity at times is a consequence of their migratory habits, and the circumstance that their home is then unknown to the fishermen. The Red Mullet feeds on small crustacea and thin-shelled mollusca.

FAMILY VI.—SPARIDÆ.

The Sparidæ are a large natural family, including upwards of twenty genera, and a multitude of species, which are commonly known as the Sea Breams. These fishes have the body compressed and oblong. The scales are minutely serrated; the branchiostegal rays vary from five to seven; the bones of the head have a rudimentary system of mucus canals; the dentary organs are either of a grinding character at the sides of the jaws, or are cutting teeth placed in front of them. The air-bladder is often divided posteriorly. Dr. Günther divides these fishes, some of which are herbivorous and others carnivorous, into five groups, which are named from typical genera.

THE BLACK SEA BREAM, OR OLD WIFE.†

This is a fish of solitary habits, which frequents the west and south coasts of England and Ireland in summer and autumn, but ranges southward to the Mediterranean Sea and Canary

* *Mullus surmuletus*.

† *Cantharus lineatus*.

Islands. It feeds and fattens on delicate seaweeds, but readily takes the hook when baited with Mussel. It reaches a length (exclusive of the fins) of seventeen inches and a depth of five inches and a half. It is not greatly valued for food. It is sometimes flesh-coloured on the cheeks, green on the back, and reddish-yellow on the body, but when the colours fade Couch states that it acquires a dull sooty tint; but the colour varies with the season. The fins are blackish-grey. There are ten vertebrae in the abdomen and fourteen in the tail. The other species of this genus are found in the Mediterranean, Cape Seas, and Indian Ocean.

Box vulgaris, called the Bogue, has remarkable crenulated incisor teeth. It is rare on the south coast of England, but ranges to the Mediterranean, Canary Isles, and Caribbean Sea. Couch's Sea Bream (*Pagrus orphus*), a rare visitor to the Cornish coast, is better known from the Canaries. *Pagellus erythrinus* is a red fish, ranging from the mouth of the Danube to the Canaries, and northward to English shores. *Pagellus oweni* is another Sea Bream, which, however, is known only from the British seas. The Common Sea Bream (*Pagellus centrodonatus*) is one of the commonest of British fishes, breeding in late autumn or winter. In severe seasons it retires to great depths. At the close of summer it assembles in schools, when 20,000, or even 60,000, have been taken in the seine net. When thus abundant it has been sold for half-a-crown the hundred-weight. It feeds indifferently on small fishes, crustaceans, and seaweeds. The Gilthead (*Chrysophrys auratus*) is an allied Mediterranean fish, which occasionally reaches the coasts of Cornwall and Devon. All the Sparidae are acutely sensible to change of temperature, which influences their place of habitation in the sea.

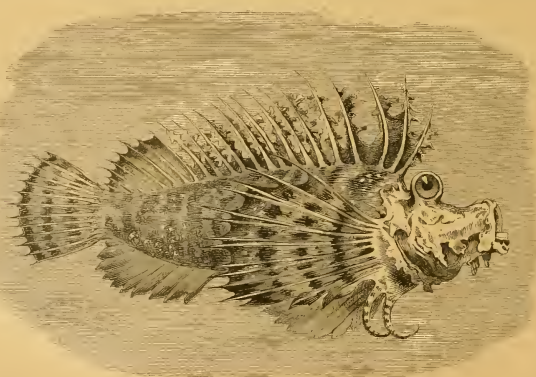
Many of the families which follow are chiefly remarkable for the minor peculiarities of structure, or geographical distribution, to which attention is briefly drawn.

FAMILY VII.—HOPLOGNATHIDÆ.

The Hoplognathidæ, which have compressed and deep bodies, have the bones of the jaws forming a sharp dentigerous edge. The three species are limited to the seas of China, Japan, and Australia.

FAMILY VIII.—CIRRHITIDÆ.

The Cirrhitidæ are a family with the body compressed and oblong. The branchiostegal rays vary from three (in the genus *Nemadactylus*) to as many as six. The lower rays of the pectoral fin are not



FELOR FILAMENTOSUM.

branched. The family includes eight genera, which are confined to the tropics, though some species range farther south.

FAMILY IX.—SCORPÆNINÆ.

The Scorpeninæ are a family of twenty-four genera, distinguished by having a bony support for the angle of the pre-operculum; the family includes two sections, one with distinct scales, and the other with rudimentary scales, or none at all. Among the genera are the widely distributed *Sebastes*; *Scorpena*, characterised by having a groove on the occiput; *Taenianotus*, which has the dorsal fin continuous with the caudal fin; *Enneapterygius*, which has three separate dorsal fins; *Amphiprionichthys*, in which the pre-operculum and operculum are small, and do not cover the gill membrane; and *Synanacidium*, *Synanctia*, and *Pelor*, in which the head is of irregular and monstrous form. *Pelor filamentosum* is from Mauritius. *Pterois* has the spines and rays of the fins elongated and branched. These, with the other genera in the family, are mostly from tropical seas, especially the Archipelago of the Indian Ocean. They comprise some of the ugliest of known fishes. The large development of the pectoral fin, and the existence of pectoral appendages, give them at first sight some resemblance to the Gurnards.

FAMILY X.—POLYCENTRIDÆ.

The Polycentridæ include two genera of carnivorous fresh-water fishes from Tropical America. The lateral line in them is absent, and the teeth are very small. *Monocirrhus* has a barbel to the mandible, which is absent in *Polycentrus*; both genera have a long spinous anal fin.

FAMILY XI.—TEUTHIDIDÆ.

The Teuthididæ are a family formed for a single genus of herbivorous fishes frequenting the tropical parts of the Indian Ocean, and adjacent seas, and the west coast of the Pacific. The ventral fin has a spine both on its inner and outer margins.

Dr. Günther's second great division of the Acanthopterygian fishes is termed *Beryciformes*; it comprises the one family *Berycidæ*.

FAMILY XII.—BERYCIDÆ.

These fishes have the body compressed and elevated; the head has large mucus cavities covered with thin skin. The type genus *Beryx* has some of the species limited to the sea about Madeira, and others occurring in the Australian region. The opercular bones are serrated, but the pre-operculum has no spine. The scales are of the ctenoid pattern, usual in the family. In the genus *Monocentris* the scales are large, bony, and form an armour to the body.

The third division is named *Kurtiformes*; it includes

FAMILY XIII.—KURTIDÆ.

These comprise two genera of East Indian fishes, characterised by having a long anal fin, and one dorsal fin, which is rather short. The colour of the genus *Peumpheris* is usually reddish-brown, or violet-brown, with bright coloured fins, and various spots on the body. The tail vertebrae in this genus gradually become more elongated posteriorly; the abdominal vertebrae are very short.

The fourth division, *Polynemiformes*, includes

FAMILY XIV.—POLYNEMIDÆ.

There are three genera—*Polynemus*, from Indian Seas; *Pentanemus*, from the west coast of Africa and the Caribbean Sea; and the genus *Galeoides*, from the river Niger and adjacent coast of Africa. This group has two short dorsal fins, which are remote from each other, and several appendages below the pectoral fin, which are entirely free and jointed. The mucus system in the head is well developed, and the air-bladder is sometimes absent, sometimes attains a large size, and is occasionally excessively minute in species nearly allied to each other.

The Scieniformes include only

FAMILY XV.—SCIENIDÆ.

Of the Scienidæ there are thirteen genera, some temperate and some tropical, with a few species inhabiting the fresh waters of America, Africa, and the East Indies. There are no filaments in the

pectoral region, but the mucus system of the head is well developed. The soft dorsal fin is much more developed than the spinous dorsal, or than the anal fin. The air-bladder, which is sometimes absent, usually has greatly elongated appendages.

In the British seas there are two representatives of this family, the *Umbrina cirrhosa*, which ranges into the Mediterranean, where it is common, and extends as far south as the Cape Seas, and secondly the *Sciaena aquila*, commonly known as the Maigre. It rarely attains a length of three feet, but has been taken more than six feet long. It is a strong fish, and difficult to get into small



MAIGRE.

boats. The otoliths, or ear bones, are larger in proportion to the size of the fish in this species than in any other. Its head has always been highly valued by the epicure, and was formerly presented as a tribute to the magistrates of Rome. Yarrell quotes the history of the head of one of these fishes. This head was presented to the nephew of Pope Sixtus X., and he in turn gave it to one of the cardinals; from him it passed to his banker, to whom he was under obligations; and the banker presented it to his mistress. Its wanderings were followed by a man whose industry was rewarded at last by a share in the feast. This story forms much of the underplot of Beaumont and Fletcher's *Woman-hater*. The air-bladder in this species, as indeed in the whole genus, gives off processes all round its margin, which branch and subdivide into a perfect fringe. The fins are brown, the body bluish-white below, and greenish-brown above.

The division Xiphiiformes includes only

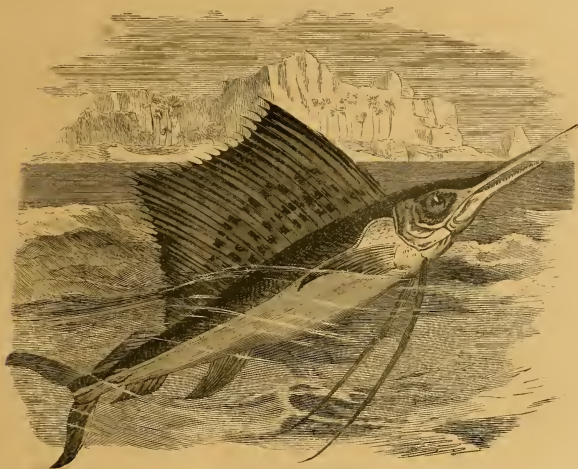


COMMON SWORD-FISH.

FAMILY XVI.—THE XIPHIIDÆ, OR SWORD-FISHES.

Of these there are two genera. *Xiphias*, the Common Sword-fish, abounds throughout the Mediterranean Sea and the European Seas, and extends along both sides of the Atlantic. The second genus, named *Histiophorus*, comprises the Flying Sword-fishes, which reach quite as large a size as the British type, and are distinguished by the enormous size of the dorsal fins. The Common Sword-fish (*Xiphias gladius*) in these seas sometimes reaches a length of ten feet, and then the sword in front of the orbit of the eye measures three feet five inches. It has once been taken in the river Nen, below Peterborough.

It has often been met with in Scotland, and ranges into the Baltic. Captain Crow is answerable



FLYING SWORD-FISH.

for the celebrated story of all hands being called up at three o'clock in the morning near the Hebrides to witness a battle between some Sword-fishes and Fox Sharks on the one side, and an immense Whale on the other. Almost every captain on the east coast professes to have seen an exactly similar conflict. It is well known that the sword is sometimes driven into the bottom of a ship. Dr. Leach records finding small Sword-fish in the stomach of a large one, but Scottish specimens contained the kind of Cuttle-fish called the Calamary.

The young Sword-fish is eaten on the shores of the Mediterranean. The sword in the upper jaw is depressed and flat, and extends far in advance of the lower jaw. In small specimens the dorsal fin is high and greatly elongated, and the lower jaw is relatively much longer than in the adult. The allied genus *Histiophorus* is also devoid of scales, but the skin contains slight dermal ossifications. This genus, unlike *Xiphias*, is supplied with small teeth in the jaws and on the palatine bones.

The seventh division, the Trichiuriformes, also includes but one family, in which there are seven genera.

FAMILY XVII.—TRICHIURIDÆ.

These fishes are characterised by having the body elongated, like a band, and have several strong teeth in the jaws, or on the palate. The dorsal and anal fins are long, and formed of many rays. Some forms are naked, others have minute scales; the tail is sometimes furnished with little fins. These fishes chiefly inhabit the seas between the Tropics, and extend into temperate regions, such as the Mediterranean, and are represented in British seas by the Scabbard-fish (*Lepidopus caudatus*) and the Silvery Hairtail (*Trichiurus lepturus*).

The Scabbard-fish is only occasionally met with on English shores. It has pointed and cutting teeth, two round scales in place of ventral fins, and a third triangular scale behind the vent. These are the only scales on the body. The dorsal fin commences at the nape of the neck, and extends the length of the body. The largest specimens are five to six feet long, and weigh, without the intestines, six pounds. There are forty-one abdominal vertebrae, and seventy-one in the tail. *Trichiurus* is a very rare visitor to the British coast, but is taken in the West Indies and Atlantic coasts of America. It has no scales, and the tail terminates like a whip. The spines of the anal fin are hidden beneath the skin. The ventral fins are represented by a pair of scales.

The Cotto-scombriformes is another division, including fourteen families of fishes.

FAMILY XVIII.—ACRONURIDÆ.

These are herbivorous fishes from the tropical seas, and include five genera which have one dorsal fin with several prominent spines, and one or more bony spines on each side of the tail. The teeth, which are always closely set in a single series, are sometimes lobate. The intestine is greatly convoluted.

The second section of this division includes the bulk of the fishes allied to the Scombroids.

FAMILY XIX.—CARANGIDÆ.

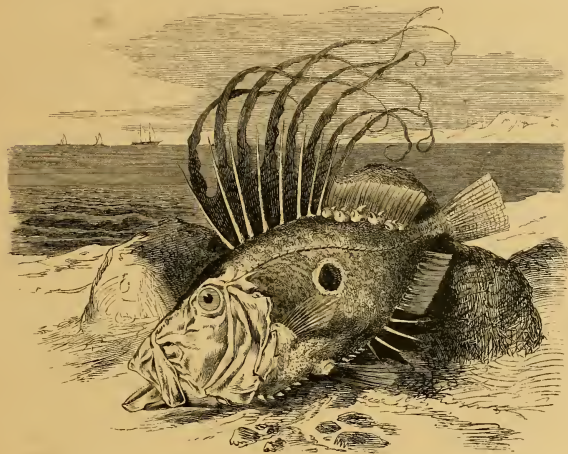
These fishes have ten vertebrae in the abdomen and fourteen in the tail. The soft dorsal and anal fins are of nearly equal extent, and the body is compressed and oblong. The best known member of this group is the Horse Mackerel (*Trachurus trachurus*), which occurs on the temperate coasts of Europe, and ranges, by way of the Cape of Good Hope, through the Indian Seas, to New Zealand, and along the western coasts of America. It is often known as the Scad. It has been caught in the Bristol Channel with the seine net in July, when following the fry of the Herring. It regularly visits the coasts of Cornwall and Devonshire in schools. It makes its appearance in May, and becomes more abundant as the season gets warmer. Ten thousand have been taken at a single cast of the seine on the Cornish coast. When following the Sand Launce, which is a favourite food with these fishes, they frequently come so near to the shore as to be taken by hand. They are not often eaten, though salted in some parts of Cornwall. The flavour is said to be inferior to that of Mackerel, though somewhat resembling it. They reach a length of twelve inches. They are largely fed upon, when young, by sea-birds, and Couch describes the multitude of gulls which pursue them so that there is no room on the surface of the sea for more, and the last comers can alight only on their comrades; while the gulls thus feed from above, the diving birds hunt the fishes from beneath.

The first dorsal fin has eight bony rays, the second dorsal fin is long. There is a small fin with two rays in front of the anal; the colour is usually dusky green on the back. The lateral line is armed with plates, which towards the tail are elevated into a ridge.

FAMILY XX.—CYTTINA.

This family comprises three genera of Scombroid fishes, well represented in British waters by the *Zeus faber*, commonly known as the John Dory, which is distributed round the Atlantic coasts of Europe, extends into the Mediterranean, and is known from the Australian Seas. The body is greatly compressed and oval; the jaws of the large head can be greatly extended; the small teeth are placed in a single row in each jaw. The spines of the first dorsal fin are very long, and the membrane between the spines is produced into very long, slender filaments. The second dorsal fin has its rays short. The anal fin has its first spinous rays elongated. A row of spiny

scales extends along the bases of the dorsal and anal fins on each side. The body is usually a pale olive-brown, with a large circular spot, nearly black, upon the middle of the side. This fish is most abundant in the summer and autumn. Couch records that he has taken from the stomach of one Dory twenty-five Flounders, three Father-lashers, and five stones from the beach. Usually it is a sluggish fish, but at times becomes active in pursuit of prey. Pilchards, the young of the Sea Bream, and the common Cuttle-fish are favourite items of food with it. It has always been highly valued for the table. It was, we believe, Archbishop Whately who declared that the proper companion for John Dory was Ann Chovy. The largest examples mentioned by Couch have a length of twenty-two inches and a weight of eighteen pounds. When dying the colours fade, but are regained when the fish is dead. The ingenious inventors of legends have disputed whether



JOHN DORY.

it was not the Dory rather than the Haddock which St. Peter took from the Lake of Gennesaret and marked with his finger and thumb while taking the tribute money from its mouth. Other authorities in the matter of legends maintain that while St. Christopher, wading through an arm of the sea, was carrying the Saviour he caught a Dory and left the impressions from his hand on its sides as an everlasting memorial to be handed down to the fish's posterity.

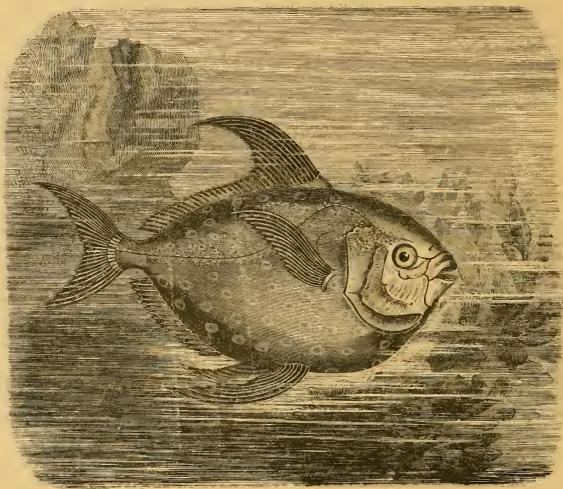
FAMILY XXI.—STROMATEINA.

This family is represented in the British seas by the Black-fish. In this group the sharp margins of the jaws are bordered with minute teeth, and though the palate and tongue are smooth, the œsophagus is armed with numerous bony teeth, which are barbed. The Black-fish (*Centrolophus pompilus*) is a rare visitor to the British coast. Couch obtained specimens thirty-two inches long, though its size is generally smaller. The flavour is delicious. The colour is usually black. A second British species (*Centrolophus britannicus*) is described by Dr. Günther. Its stomach was found to be full of seaweed, and Couch states that the bones of the head and back were as soft as cartilage. The colour is brown, and the species is distinguished by its great length relatively to the height, and

by the great length of the dorsal fin, which extends between the head and tail. The caudal fin is forked.

FAMILY XXII.—CORYPHÆNINA.

This family has no teeth in the œsophagus. It includes nine genera, most of which occur in the Mediterranean and Eastern seas, and among other fishes Ray's Bream and the Opah. The Ray's Bream (*Brama raii*) ranges from the Cape Seas northward into the Mediterranean and along the British coast. It is about seventeen inches long, exclusive of the fins, and five inches and a half deep. The tail is deeply divided, and the dorsal and anal fins are elongated and have



OPAH.

the first few spines produced beyond the others. The pectoral fins are long. The Opah (*Lampris luna*) is a remarkable type, with a compressed, elevated body, covered with small scales, which are deciduous. The fins are all red; there is no spinous portion to the dorsal fin; the ventral fins are placed behind the middle of the body. The back and sides are a rich green with purple and gold reflections; the body becomes yellowish-green or bluish below, and is covered with white spots. Its flesh is red or yellowish, and is said to have a sweet and rich flavour. Individuals attain a large size, but the specimens usually captured do not reach a length of four feet. It is well known in the North Atlantic, and enters the Mediterranean.

FAMILY XXIII.—NOMEINA.

The members of this family are scombroid fishes, with an oblong body covered with cycloid scales, having two dorsal fins, of which the soft dorsal is the more developed. The family includes six genera, among which are *Gasterochisma*, remarkable for having a deep fissure on the abdomen, in which the long and broad ventral fin can be completely concealed. The only species, *Gasterochisma*

melampus, is from New Zealand. The genus *Nomeus* has a similar characteristic, but the ventral fin is attached to the belly by a membrane.

FAMILY XXIV.—SCOMBRINA.

This is an important family, including among other fishes the Mackerel and the Tunny. There are always two dorsal fins, the spinous fin being less developed than the soft dorsal fin. In one genus the spinous dorsal becomes modified into a sucking organ, which is situated on the head. The genus *Scomber* inhabits nearly all the temperate and tropical seas, but is absent from the temperate coasts of South America.

THE MACKEREL.*

Hardly any fish is better known in the South of England than the Mackerel. It spawns in June, and then comes into shallow water, and 550,000 eggs have been counted in a single female. When the fish are young, under six inches long, they are termed "Shiners;" they are half grown by November, and retire into deep water at the approach of winter. Their growth is very rapid. The ordinary size ranges to a length of about fifteen inches and a weight of about two pounds, though the fish are sometimes longer and heavier. They are in the best condition in May and June. Yarrell remarks that, owing to the necessity that the fish should be eaten fresh, they were first allowed to be cried on Sundays through the streets of London in 1698, and that the practice continues to the present time. Their abundance varies: in 1807 they were sold in Billingsgate at seven shillings each; at Dover, in 1808, they were sold at sixty a shilling; and at Brighton in the same year the school was so great that it was impossible to pull the fish in, and fish and nets sank together. Mackerel are taken in every month of the year, but the great shoals begin to move into the English Channel from the deep waters of the Atlantic in January. In the migration the males precede the greater part of the females. They reach the Shetland Isles in August, and remain in that neighbourhood about a month. A few Mackerel of small size occur in the Baltic, and they reach the coast of Norway.

This fish is exceedingly voracious, and feeds upon the fry of other fishes. It ranges along the European coast into the Mediterranean, where it is often of small size and dry in flavour. It extends across the Atlantic, and is found on the American coast in corresponding latitudes. The scales of the Mackerel are exceedingly small; there is no air-bladder. The back, as is well known, is bluish and marked with about thirty wavy transverse streaks of a blackish colour. Couch mentions that occasionally a lobe of roe has been found lying between the usual pair of lobes of milt, so that the sexes are sometimes united in one individual. The fish are captured sometimes with the hook, baited with a bright shining object, but more frequently they are taken with the seine net.

At Brighton and along the Chesil Bank the fishing is carried on by means of the ground seine net, which can be used whenever the bottom is smooth, and there is a beach on which it can be landed. The meshes of the net are small, and it is not nearly so deep at the two ends as in the middle. Each end or wing is bordered by a pole fastened to the ropes on the back and foot; and to this pole a long rope is fastened, to be used for hauling in the net to the shore. When the seine is to be shot one of these drag-ropes is left on shore in charge of some of the party, and the other rope with the nets is rowed out to sea and back again in a large sweep, the net being thrown over as they go along. On landing, the fishermen divide and haul in the net, bringing the two ends together; then the middle of the net, which is called the bunt, is drawn on shore, and contains whatever fish have been intercepted.

The Spanish Mackerel (*Scomber colias*) is occasionally taken on the Cornish coast, and occurs on the Atlantic shore of North America, and in the Mediterranean. It is inferior to the common Mackerel for table, and is distinguished by having a larger head and spotted sides. There are large scales on the pectoral region, and, according to Dr. Günther, it possesses an air-bladder. There are probably one or two other British species, and several species occur in the Red Sea and seas of Japan and the Malay Islands.

Another important fish of this family is known to us as the TUNNY (*Thynnus thynnus*).

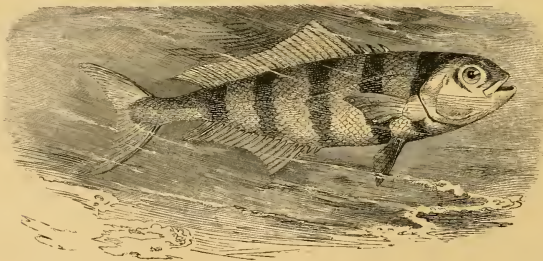
* *Scomber scomber*.

The body of the Tunny is much thicker than that of the Mackerel; the teeth are rather small, and exist in the jaws and on the palatine bones and vomer. The pancreatic appendages are extremely numerous, and the air-bladder is absent in some species of the genus. The scales of the pectoral region form a distinct covering for the throat. There is a keel on the middle of each side of the tail.

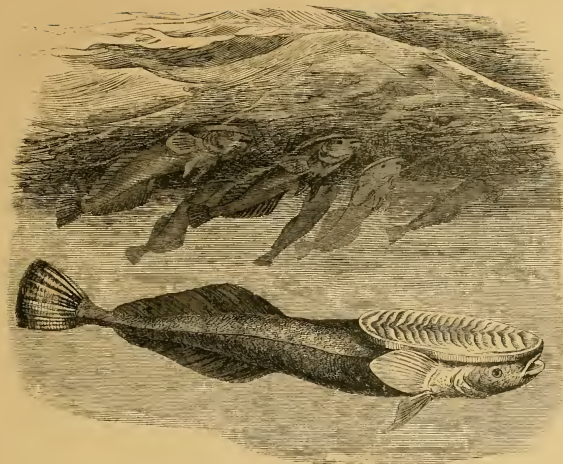
The Tunnies are widely distributed, and are especially fishes of the open ocean. The British form occurs on both sides of the Atlantic and in the Mediterranean, in which latter locality it is associated with several other species. A specimen in the British Museum, taken at Weymouth, is eight feet long. Such a fish would probably weigh five hundred pounds, but they are rarely met with of a greater length than three feet. They feed on Herrings, Sardines, Flying-fish, Mackerel, and probably many other fishes smaller than themselves. The Tunny harvest in the Mediterranean is of the utmost importance to the countries near which the fishes pass. They come in from the Atlantic in vast multitudes, and journey through the Strait of Gibraltar by way of Sicily on to the Black Sea. Toll is taken of them on every shore they pass by. After leaving the Black Sea they swim back again along the southern shore of the Mediterranean, and pass out into the Atlantic. It has been observed that the Tunny possesses so much blood that its flesh has the appearance of beef, and its temperature is as high as that of a mammal; nevertheless, it breathes by means of gills, and the heart is shaped on the plan characteristic of fishes. The colour of the skin above is dark blue, the under side of the body is greyish. The head is large and conical, and one-fifth of the length. The pectoral fin is long, and reaches to near the end of the spinous dorsal fin. The dorsal spines are rather short.

Another species of this genus, the *Thynnus pelamys*, is sometimes known as the BONITO, and sometimes called the Striped-bellied Tunny. It ranges through the warmer parts of the Indian Ocean and Atlantic, and at times visits Great Britain. It seldom exceeds thirty inches in length, feeds on fish, especially the Flying-fish, and also eats Cuttles. It has been recognised in various parts of the British coast, has red muscles, few teeth, and a flat and thin tongue. The colour is steel-blue on the back, with four brownish longitudinal stripes on the sides of the belly. Another British species is the GERMON (*Thynnus alalunga*), distinguished by the great length of the pectoral fin, which reaches beyond the end of the second dorsal fin. It is rare in the English Channel, but plentiful in the Bay of Biscay. It is stated that the fishermen of Ile d'Yeu capture thirteen or fourteen thousand in a season with hooks, which are often baited with pieces of bright tin, shining earthenware, or blue or white cloth. The Germons feed on Anchovies, Pilchards, Flying-fish, &c. The other species of this genus are met with in the Red Sea, Indian Ocean, and Caribbean Sea.

The next genus, *Pelamys*, has the first dorsal fin continuous with the second, and usually from seven to nine little finlets; the dorsal and anal fins are similar to those which occur in the Tunny and Mackerel. *Pelamys sarda* reaches a length of fully two feet; it is not abundant on the



PILOT-FISH.



SUCKING-FISH, OR REMORA.

British Coast, but frequents both sides of the Atlantic, and ranges throughout the Mediterranean and Black Seas. There is the same corselet of scales in this genus in the pectoral region which characterises the Tunny.

The genus *Auxis* is represented in British seas by a fish commonly known as the Plain Bonito (*Auxis rochei*). It has but little value as food.

The Pilot-fish (*Naucrates ductor*) has a long, somewhat cylindrical body, covered with small scales. The spinous dorsal fin is reduced to a few short free spines. The fish has a bluish colour, marked with five to seven vertical bars, which are dark and broad. It often follows ships for weeks, or even months, and it is also said to follow large sharks; and anecdotes have been recorded which would appear to indicate that the relations between these two fishes were of a friendly character. The Pilot-fish is usually about a foot long; it feeds on small fishes, and its flavour is said to be similar to that of the Mackerel.

THE SUCKING-FISH, OR REMORA.*

All the species of the genus *Echeneis* have a flat, oval disc on top of the head, which is formed of a number of transverse plates constituting a sucking organ, by which these fishes are capable of adhering. The border of the disc is elevated, and the water is driven out by contraction of the laminae. The attachment, when once made, often continues after death. These fishes are brown in colour, occur in nearly all temperate and tropical seas, especially in the Pacific and East Indies. The Remora attaches itself to sharks, whales, or ships, and is carried by them for great distances. It is rarely met with in the British seas; its length is about four inches and a half. The sucking disc has a cavity for its reception excavated in the upper part of the skull.

Another well-known species is the *Echeneis naucrates*, specimens of which in the British Museum have a length of thirty-two inches. The suctorial disc is formed of from twenty-one to twenty-five laminae; there are fourteen vertebrae in the abdomen and sixteen in the tail. The latter vertebrae are compressed and elongated.

* *Echeneis remora*.

CHAPTER V.

ORDER ACANTHOPTERYGII (*continued*).

THE TRACHINIDÆ—*Uranoscopus*—Star-gazers—The Greater Weever, or Sea Cat—The Lesser Weever—THE MALACANTHIDÆ—THE BATRACHIDÆ—THE PEDICULATI—THE SEA DEVIL, or ANGLER—Its Voracity—The Genus *Malthe*—COTTINA—THE MILLER'S THUMB, or RIVER BULLHEAD—THE SEA SCORPION, or FATHER LASHER—The Gurnards—THE CATAPHRACTI—THE COMEPHORIDÆ—THE DISCOBOLI—The Lump-sucker, or Lump-fish—The Sea-Snail—THE GOBIIDÆ—THE OXUDERCIDÆ—THE CEPOLIDÆ—THE TRICHONOTIDÆ—THE HETEROLEPIDIDÆ—THE BLENNIIDÆ—The Wolf-fish, or Cat-fish—The Butterfly Blenny—The Shanny—The Viviparous Blenny—THE ACANTHOCLINIDÆ—THE MASTACEMBELIDÆ—THE SPHYRINIDÆ—THE ATHERINIDÆ—The Sand Smelt—THE MUGILIDÆ—The Grey Mullet—THE GASTEROSTEIDÆ—STICKLEBACKS—The Three-spined Stickleback—Its Pugnacity—The Nest—The Ten-spined Stickleback—The Nest—The Fifteen-spined Stickleback, or Sea Adder—The Nest—THE FISTULARIDÆ, or PIPE-FISHES—THE CENTRISCIDÆ—The Trumpet-fish, or Bellows-fish—THE GOBIESOCIDÆ—THE PSYCHROLUTIDÆ—THE OPHIOCEPHALIDÆ—The Walking-fish—THE LABYRINTHICI—Supra-branchial Organ—The Climbing Perch—THE LUCIOCEPHALIDÆ—THE APHREDODERIDÆ—THE LOPHOTIDÆ—THE TRACHYPTERIDÆ—THE NOTACANTHI.

FAMILY XXV.—TRACHINIDÆ.

THE Trachinidæ are a family of carnivorous fishes comprising four or five groups of genera which feed at the bottom and are met with on the shores of nearly all seas. The first group, *Uranoscopina*, includes several genera which have the eyes on the upper surface of the head, which is defended with bony plates. The body in these fishes is sometimes naked and sometimes partly covered, or even entirely covered, with small scales. The best known genus, *Uranoscopus*, comprises about ten species, which are familiarly termed star-gazers. They are said to bury the snout in the sand and capture their prey as it crawls slowly by them. *Uranoscopus scaber* occurs in the Mediterranean and off the Canary Islands. The second group, *Trachinina*, has the eyes more or less at the sides of the head, which is not armoured. Seven of the genera have the body covered with scales, and three are devoid of scales. These fishes are represented in the British seas by the Weevers, of which there are two species. The operculum in the Weevers is prolonged into a remarkable spine, which is used as an offensive weapon. The ventral fins are under the throat, and the anal fin extends the length of the under side of the body. The first dorsal fin, placed behind the head, contains six or seven spines; and the second dorsal fin is elongated like the anal fin, but does not extend quite as near to the tail. The fish frequently buries itself in the sand, where it may be left covered up between tides.

The *Trachinus draco*, or Greater Weever, is sometimes known as the Sea Cat. It generally measures about a foot to eighteen inches in length. It is sometimes taken with a trawl net, and sometimes on deep sea lines. The fishermen are liable to be wounded by its spines, injuries from which affect the limb as high as the shoulder, so that it becomes necessary to rub the wound with oil and laudanum. In France and Spain the fishermen are required to cut off the spines before the fish, which is excellent eating, is sent to market. It is tenacious of life, and, in common with other fish which frequent the bottom, keeps good for several days after it is taken from the water. Couch mentions having found in their stomachs Gobies, the Sand Lance, a Squid, and various small fishes and shrimps. It extends along the European coast, throughout the Mediterranean, and along the African coast to the Cape seas.

The Lesser Weever (*Trachinus vipera*) is frequently found on the sandy coast of Lincoln and Norfolk. Its habits are similar to those of the Greater Weever. It spawns in spring, while the Greater Weever spawns in summer. Its usual length is four or five inches; the colour is yellowish-brown, and the body is relatively deeper than that of the Great Weever. It frequents the western coasts of Europe and the Mediterranean. Other genera of this group, such as *Percis* and *Sillago*, are found in Eastern seas; *Eleginus*, *Episcopus*, and *Percophis* are genera found on the American coasts. Other genera are Arctic and Antarctic.

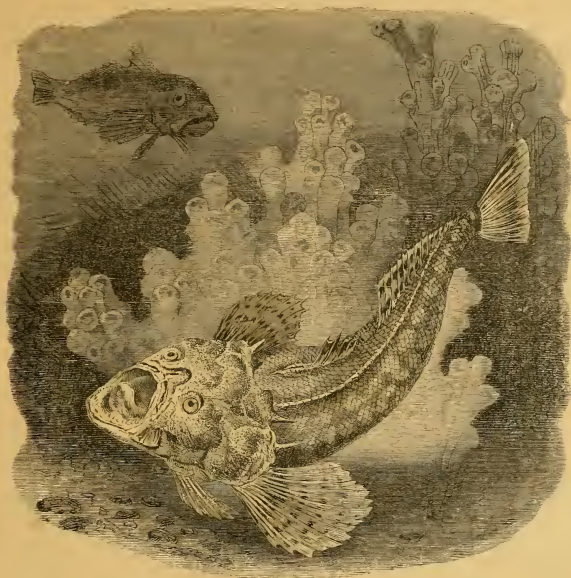
The third group, *Pinguipedina*, includes two genera of which the species are chiefly American. The fourth group, *Pseudochromidæ*, comprises half-a-dozen genera which have a similar distribution.

FAMILY XXVI.—MALACANTHIDÆ.

The Malacanthidæ are a tropical family represented by one genus having very long dorsal and anal fins, and an operculum armed with a spine.

FAMILY XXVII.—BATRACHIDÆ.

This is a small family of tropical fishes, which feed on the bottom, and includes some species which are naked and others covered with scales. The *Batrachus didactylus* is sometimes met with in the German Ocean, but more frequently between the coast of Portugal and the Guinea Coast of Africa. It is remarkable for the circumstance that the air-bladder, which is divided into two lateral portions connected by a transverse tube, has but a small internal cavity, owing to the immense development of muscle attached to the sides of each portion of the bladder.



URANOSCOPUS SCABER.

FAMILY XXVIII.—PEDICULATI.

The Pediculati comprise some of the ugliest of fishes, among which may be instanced such genera as *Lophius* and *Malthe*. In these fishes the carpal bones are prolonged, so as to form a sort of arm for the support of the pectoral fins, which sometimes, as in the genus *Malthe*, have the aspect of legs, and give the fish a frog-like appearance. In English seas there is only one representative of this remarkable group, the majority of which are tropical.

THE SEA DEVIL, OR ANGLER.*

The great breadth of the head and anterior part of the body, no less than its depressed form, gives this fish somewhat the aspect of a gigantic tadpole. It is met with on almost all parts of the

* *Lophius piscatorius*.

British coast, and along the shores of Europe, and ranges southward in the Atlantic to the Cape of Good Hope. On the head of this voracious animal are two or three detached rays of the dorsal fin, which are extended as long filaments and terminate upward in bright shining surfaces. Keeping close to the bottom, the fish is said to stir up the mud by moving its ventral and pectoral fins, and at the same time elevates these appendages; then, as small fishes approach to examine the bait, they are immediately seized by the Angler. It has been known to seize Codfish and Conger Eels after those fishes had taken the fisherman's hook. Couch records that nearly three-quarters of a hundred of Herrings have been taken from the stomach of a single Angler, in a condition fit for market, and that another individual similarly yielded up twenty-one Flounders and a Dory, which also found their way to market; so that the digestion of the fish is apparently very slow. On one occasion some boys thrust a board into the mouth of a large Angler, which was seen in shallow



MALTHE VESPERTILIO.

water, and the fish allowed itself to be drawn into their boat without releasing its hold. One Angler has been seen endeavouring to swallow a Gull, and another had seized a Great Northern Diver (*Colymbus glacialis*); but its appetite is so little discriminative that it has swallowed the cork buoys of a crab-pot, the floating barrel fixed to the head-rope of a pilchard-net, and the iron grapnel of a fisherman's boat. This fish reaches a length of about five feet. The roe, which is small, is computed to contain about a million and a half of eggs; but the young fish are so rare as to be almost unknown. The gape of the mouth is extremely wide; the teeth are arranged in alternate series, and are constantly renewed from behind. The aperture for the gills is a small foramen placed just behind the pectoral fin.

Dr. Gunther remarks that the species of the genus *Antennarius*, which inhabit the seas between the Tropics and feed on floating seaweed, are enabled to fill the large stomach with air so as to sustain themselves on the surface of the water, and thus become driven by currents over wide regions of the ocean. The genus *Malthes* has the nasal bones prolonged over the forehead into a prominent process, below which is a tentacle capable of being retracted into a cavity. The skin has a rough aspect from being covered with conical protuberances. The snout in *Malthes vespertilio*, which inhabits the Atlantic coast of America, varies in length, being sometimes as little as one twenty-fifth of the total length of the fish, and sometimes as much as one-sixth of the length in Brazilian

specimens. There are eight vertebræ in the abdomen and eleven in the tail. Some of the anterior and posterior vertebræ are elongated.

FAMILY XXIX.—COTTINA.

The family Cottina comprises the Gurnards and about eighteen genera of allied fishes, some of which have the body naked, while in others it is covered with ordinary scales, and in a few defended with scales like bony plates.

THE MILLER'S THUMB, OR RIVER BULLHEAD.*

This little fish grows to a length of three or four inches, and derives its name of Bullhead from the head being large and broad and swollen at the cheeks. It is white on the underside, but brownish-black above, with small black spots and bands over the back and sides. It feeds on the larvæ of water-insects and the eggs and young of other fishes, and is readily caught with a small red worm. It is extremely active, darting about from place to place, and undergoes many changes of colour under exertion and after feeding. It is found not only in all the sandy and gravelly streams of Great Britain, where it hides itself under stones, but throughout Europe and in the north of Asia. Its skin is slippery. The female is said to carry the eggs on her breast after spawning, but some writers state that after depositing them in the gravel she broods over them till they are hatched. Cuvier found the Bullhead to be an excellent bait for the Eel. Yarrell, quoting James Wilson, states that the flesh of the Bullhead becomes red when boiled, and is excellent eating.

THE SEA SCORPION, OR FATHER LASHER.†

This is a marine Bullhead found on the coasts of Britain and the German Ocean; it is also met with in the Baltic. It has the head armed with spines, two above the snout, four on the crown, and three on the pre-opercular bones. The skin is usually naked, and black with grey marblings



SEA-SCORPION.

The males are more richly coloured. It lives on the smaller crustacea, and is often caught in the shrimp-nets. It is commonly found near to shore, where it is often left uncovered. The species enters estuaries and sometimes ascends rivers. The *Cottus bubalis* closely resembles the Father Lasher, and like that species grows to a length of four or five inches, but it is more slender, has four opercular spines,

* *Cottus gobio*.

† *Cottus scorpius*.

has the lateral line armed with bony plates, and affects deep water. According to Couch, its colour is a mottling of red and brown. It is frequently found in lobster-pots. A variety of it occurs on the coast of California and the Gulf of Georgia. All these fishes have the fins well developed.

The other British representatives of this family are the Gurnards, which form the genus *Trigla*. The head is elevated, with the eye near its summit; its surface is bony and marked with radiating lines; the body is covered with small scales. There are three filaments in front of each pectoral fin, which, when the animal is at rest, have the aspect of legs. There are bristle-like teeth on both the jaws and on the vomer. The air-bladder is usually divided into two parts, which are furnished with lateral muscles. The stomach forms a pouch. There are several British Gurnards, but they also range round the western coasts of Europe and into the Mediterranean. The Red Gurnard (*Trigla pini*) is a common British fish, reaching a length of about fourteen inches. It feeds on crustacea, is readily caught with a trawl, and is excellent food, especially during the winter months. The head has a squarish form, the ventral fins are placed under the throat, and all the fins are well developed. The Streaked Gurnard (*Trigla lineata*) is also red, with large pectoral fins, which are more or less spotted with blue. It has a shorter head than the Red Gurnard, and is rather smaller. The Sapphirine Gurnard, or Tub-fish (*Trigla hirundo*), has extremely small scales. The space between the eyes is concave; the colour is brownish-red, and the broad pectoral fins are margined with blue. The snout is rather elongated. It lives among stones, and feeds on shell-fish, crabs, and other fishes. The air-bladder in this species is divided into three lateral lobes. In some European languages the grunting or crowing noises which these fishes produce have gained for them the name of Sea Cocks. *Trigla lyra* is also known as the Piper; it is another Red Gurnard, chiefly met with in the West of England. The name Piper is in allusion to the sounds emitted when the fish is handled. This species reaches a length of two feet. The Grey Gurnard (*Trigla gurnardus*) is by far the most abundant British species. Its head is more depressed than in the other species; the lateral line carries a series of bony plates, which are white, and each has a rough crest. The pectoral fin does not reach as far back as the beginning of the anal fin, which distinguishes it from the other British species. The colour is brownish-grey, spotted with white.

FAMILY XXX.—CATAPHRACTI.

The next family, the Cataphracti, is a group of genera distinguished by having the body completely encased in bony plates, or scales, which are marked with keels. This family is represented in the British seas by *Agonus cataphractus* and *Peristethus cataphractum*. The former, sometimes known as the Armed Bullhead, and sometimes called the Pogge, is a little fish about six inches long, met with in the northern parts of Europe. It frequents the mouths of rivers; has a very small mouth, that is incapable of taking an ordinary hook; has a wide head, defended with bones and armed with spines. The body is covered by rows of large strong scaly plates. The colour is brown.

The *Peristethus cataphractum* is a red fish known as the Armed or Mailed Gurnard. It has a large head and remarkably long snout, the extremity of which is forked laterally. The body is octagonal and covered with a series of large plates, the middle of each of which is longitudinally keeled. The fins are well developed.

FAMILY XXXI.—COMEPHORIDÆ.

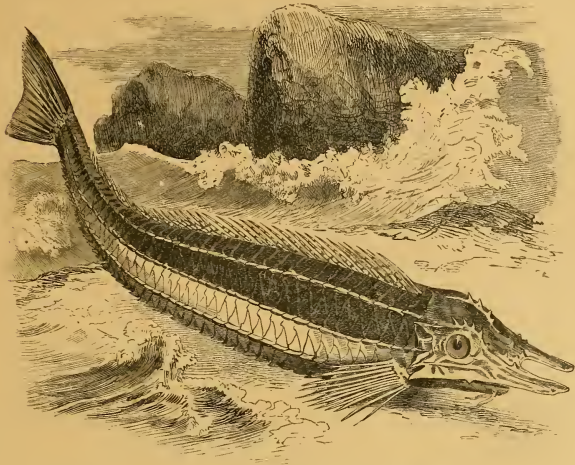
The last family of the Cotto-scombriformes is termed Comephoridæ. It is represented by a single species—*Comephorus baikalensis*, a fish of uniform green colour, having the pectoral fin longer than the head, and chiefly remarkable, according to Dr. Günther, for the soft condition of the skeleton, and the circumstance that the opercular bones are separated. There are eight vertebrae in the abdomen and thirty-five in the tail.

The ninth division of this order is the Gobiiformes, and comprises three families.

FAMILY XXXII.—DISCOBOLI.

The Discoboli are a remarkable group of carnivorous fishes living upon the sea bed. They are familiarly known as the Suckers, from the circumstance that the space between the ventral fins is occupied by a round disc which has a cutaneous margin and a base of bone. There are only two genera in this family, which are named *Cyclopterus* and *Liparis*.

The Lump-sucker, or Lump-fish (*Cyclopterus lumpus*), has a wide range round the northern coasts of Europe and the opposite coast of North America. It is a heavy-looking, ugly fish, with a rough body, covered with tubercles, of which there are four longitudinal series larger than the others. Couch states that the Seal is one of its most formidable enemies, and after capturing the fish the mammal strips off the skin before swallowing its prey. They are also fed upon by Sharks and Skates. The Lump-fish commonly has a length of ten inches. It feeds on small crustacea and young fish. The female deposits her eggs in a hollow, or sort of nest, and after they have been fertilised the male is said to keep close watch over them. After the young are hatched, the



ARMED OR MAILED GURNARD.

young fishes attach themselves by their suckers to the sides and back of the male, who carries them away with him into deep water. The spawn is of a pink colour. The male is much smaller than the female. There is very little lime in the bones of the fishes of this genus.

The Sea Snail (*Liparis vulgaris*) is often known as the Unctuous Lump-sucker. It is a northern fish, which in British seas is rarely more than four inches long. It has been stated to ascend rivers, but is usually found under stones near low water. Soon after death it dissolves on exposure to the sun. The skin is smooth, and the colour variable, often marked with irregular longitudinal dark lines on a pale-brown body.

FAMILY XXXIII.—GOBIIDÆ.

The Gobiidæ are a large family of fishes, the genus *Gobius* alone containing more than 150 species, while the family includes more than twenty genera. They are fishes having an elongated body, which is sometimes naked. They are all carnivorous, and live at the bottom. Some of the species occur indifferently in salt and fresh water. They are found throughout temperate and tropical regions. The body is always scaly, with a short head; the teeth are generally small, sometimes with distinct canines at the corners of the mouth. The ventral fins unite below the

hinder part of the pectorals into an oval disc, which, however, is not attached to the body of the fish, and hence does not form a sucking organ. The species are all small, and vary both in shape and colour. The Black Goby (*Gobius niger*) reaches a length of five inches, but is rare, and only found on the rocky coasts of Britain. It has the habit of constructing a nest. The *Gobius paganellus* is a brown fish, with darker marblings, and fins which have a bluish or blackish tinge. The Spotted Goby (*Gobius minutus*) differs from the other species in wanting the silk-like pectoral fins, and in the length of the ventral fins. The White Goby (*Latrunculus albus*) is a small fish, only known in the south of Scotland. This species is transparent.

FAMILY XXXIV.—OXUDERCIDÆ.

Some of the fishes of this family have the eyes very prominent and the eyelids well developed. One of these—*Periophthalmus*—has the muscles of the pectoral fins well developed, so that they can be used for progression upon land when these fishes, and those of the allied genus *Boleophthalmus*, come on shore to hunt terrestrial insects. One division of the family, including the genus *Amblyopus*, has the two dorsal fins united into one. It is chiefly confined to the East Indies, China, and Japan, but has one species ranging to the west coast of South America. Another section of the genus, distinguished by having the ventral fins widely separate from each other, is represented in the British seas by the Dragonet or Skulpin (*Callionymus lyra*), a species in which the brilliant colours and fin-spines undergo some changes with age and sex. The first dorsal spine is enormously elongated; the body does not reach the length of a foot. In the Dusky Skulpin the spines of the first dorsal fin are much less elongated. In this fish there are eight abdominal vertebrae, and thirteen in the tail. Other Skulpins occur in the Mediterranean, Chinese, Indian, and Malay Seas.

In the Chinese *Oxudercus dentatus* the ventral fins are entirely wanting.

The tenth division of this order, the Blennioformes, is a group comprising six families.

FAMILY XXXV.—CEPOLIDÆ.

This family is known from the one genus *Cepola*, chiefly found in the Japanese waters, but represented in the Mediterranean and on the British coasts by the Band-fish (*Cepola rubescens*). It is known in the Mediterranean from its brilliant red colour as the Red Riband and the Fire-flame. Its body is compressed from side to side, and elongated; its length is from fifteen to twenty inches; the scales are extremely small; the jaws carry on their outer margin a row of conical pointed teeth, with a short second row in the front part of the mandible. The eyes are large; nose short; and the lower jaw frequently the longer. The ventral fins are just under the pectoral fins, and the air-bladder is placed behind the other internal organs. The dorsal and anal fins are very long, and formed of soft rays which are continuous with the small pointed caudal fin. These fishes are said to feed on seaweed, crustacea, and small shells, and are eaten by the Cod and other voracious fishes, but are not valued for food by man.

FAMILY XXXVI.—TRICHONOTIDÆ.

The Trichonotidæ are a small family of carnivorous fishes from the Indian Archipelago and New Zealand, and are only known from two species.

FAMILY XXXVII.—HETEROLEPIDINA.

This is another small family from the northern parts of the Pacific, comprising the genus *Chirus*—which has several lateral lines—and the genera *Ophiodon*, *Agrammus*, and *Zaniolepis*. In all these fishes the anal fin is very long.

FAMILY XXXVIII.—BLENNIIDÆ.

The Blenniidae are a large family of carnivorous fishes, sometimes inhabiting fresh waters, but generally living on the bottom near the sea-shore. They are widely distributed over the world, and comprise upwards of thirty genera. The majority of the species are from tropical seas, though some of the genera have a distinct northern habit. There are comparatively few British representatives of the tribe.

The Wolf-fish, or Cat-fish (*Anarrhichas lupus*), is found on the temperate coasts of northern Europe and North America, and ranges northward to Greenland. Armed with formidable teeth, and having eyes which are placed much like those of a Cat, its aspect is ferocious. It fights desperately when captured, and is usually killed with blows on the head. The fish has a disagreeable smell, but the skin, which is covered with slime, is sometimes made into bags. The liver is said to be delicious, and the flesh is valued for food in Norway and Sweden. It is often taken on lines set for Cod, for its usual food consists of mollusca and crustacean animals, which the molar teeth on the palate and hinder parts of the lower jaws enable it easily to crush. It is a rapid swimmer, but lives on the bottom among the rocks. Its usual length does not exceed three feet, but individuals are sometimes as much as six or seven feet long. The colour is brownish-grey, crossed with bands, and speckled with dark spots; the belly is white. The dorsal fin extends the length of the body, and the anal fin runs along its posterior half. There are no ventral fins, and the pectoral fin is broad and rounded, and like the caudal fin.

The fishes forming the genus *Blennius* have a general resemblance to the Cat-fish, owing to the shortness of the snout and the way in which the dorsal and anal fins extend along the body. There are several species in British seas, all of which, except the Smooth Blenny, have crests on the head. *Blennius gattorugine* is rather rare northwards, but more abundant farther south and in the Mediterranean. It seldom exceeds a length of nine inches. The Butterfly Blenny (*Blennius*



BUTTERFLY BLENNY.

ocellaris) has a remarkably short snout, with long curved teeth in both jaws. The spinous part of the dorsal fin is long, and has on its hinder part a large round black spot with a white edge. It is a small species, rarely more than three inches long, lives among weeds, and feeds on shell-fish and minute crustacea. It also ranges southward into the Mediterranean. Montagu's Blenny is a somewhat smaller species, and has a transverse crest on the head. The Smooth Blenny (*Blennius pholis*) is commonly known as the Shanny; it has no appendage on the head, the dorsal fin is distinctly notched and not continuous with the caudal fin; the colour is olive-green, with irregular black spots. One that was kept in confinement devoured spiders and caterpillars, molluscs, roast beef, mutton, fowl, and, in fact, any food that was offered to it. Its colour always became dark when the water was changed. Its eyes are capable of moving independently of each other. The eggs are of amber colour and semicircular outline. Its long incisor teeth are used to separate Limpets, Mussels, and other shell-fish from the rocks. It is capable of living out of water for many days

where the ground is moist, and can endure fresh water for a short time. It is rarely five inches long.

Some species of the genus *Salarias* have the intestine three times as long as the fish. The species of the genera *Clinus* and *Cristiceps* are viviparous. The Butter-fish (*Centronotus gunellus*) is a northern species, ranging south to the coasts of Britain and France. It has a low dorsal fin running along the back, and is covered with a thick mucous secretion. The length rarely exceeds seven inches. The colour is a dappled purplish-brown. Another well-known form is the Viviparous Blenny (*Zoarces viviparus*), which ranges round the German Ocean and into the Baltic. The length is about six or seven inches, and the young, which sometimes number three hundred at a birth, are an inch and a half long when born. The body is long and compressed from side to side, with the form usual among the Blennies. The colour is pale brown. The males are smaller than the females and less numerous. The fish is not valued for food, and when boiled its bones become green.

FAMILY XXXIX.—ACANTHOCLINIDÆ.

The Acanthoclinidæ are represented by a single New Zealand species (*Acanthoclinus littoreus*), distinguished by the great number of spines in the long anal fin. It has several lateral lines.

FAMILY XL.—MASTACEMBELIDÆ.

The Mastacembelidæ include fishes from the fresh waters of the East Indies, having an Eel-like body covered with very small scales, and wanting the ventral fins. Dr. Günther remarks that these fishes are Eels in which parts of the dorsal fins are spinous.

The eleventh division is the Mugiliformes, in which three families are comprised.

FAMILY XLI.—SPHYRENIDÆ.

The Sphyrænidæ are carnivorous fishes, represented by the one genus *Sphyræna*, which is widely distributed in the tropics, especially in Eastern seas, and represented in the Atlantic and Mediterranean by *Sphyræna vulgaris*. In this fish there are two dorsal fins well separated from each other, and the ventral fins are well under the abdomen. All the species have the teeth strong, and possess twenty-four vertebrae. The air-bladder bifurcates in front.

FAMILY XLII.—ATHERINIDÆ.

The Atherinidæ are fishes with a feeble dentition, two dorsal fins, the ventral fins abdominal, and numerous vertebrae in both the caudal and abdominal regions. Several species of the genus *Atherina* enter fresh waters. In the genus *Tetragonurus* the scales are striated and keeled. This group is represented in the British seas by *Atherina presbyter*, where it is known as the Sand Smelt. It is chiefly caught in the estuaries and creeks of the south coast, especially in sandy bays. It is a well-flavoured fish. It is often taken at Brighton, where it is eaten in the winter. A broad silver stripe runs the length of its side, and covers the fifth and parts of the two adjacent rows of scales. This fish bites readily at any bait; it ranges south to Madeira and the coast of Algiers. The *Atherina hepsetus* is found in the Mediterranean, Black Sea, and Canaries; the *Atherina lacustris* is met with only in some of the smaller lakes of Italy. The other species of the genus are widely distributed.

FAMILY XLIII.—MUGILIDÆ.

The Mugilidæ are a small family of three genera, but include a large number of species. These fishes have twenty-four vertebrae, and two short dorsal fins. In the genus *Mugil* there are no true teeth in the jaws, and in the two other genera the teeth are small. The species of *Mugil* are migratory, pass a part of the year in the sea, abound in temperate and tropical regions, and feed on the organic substances which are mixed with mud and sand. The pharynx forms a sort of filter, the pharyngeal bones rejecting everything but the fine sediment. These pharyngeal bones are supported on masses of fat, so that they are somewhat elastic. The second portion of the stomach resembles that of birds; the intestines are greatly convoluted, measuring seven feet in length in a specimen thirteen inches long. *Mugil cephalus* is met with in the Mediterranean and in the lakes and rivers of North Africa, but some species are confined to fresh waters, like the *Mugil nepalensis* of Nepal.

The Common Grey Mullet (*Mugil capito*) occurs all round the coasts of Europe, and as far south as the Cape of Good Hope, and has also been met with in the Nile and fresh-water lakes of Tunis. It is the most common of the European Grey Mullet, but, like all the other species of the genus, it is very variable. It is usually seen near to the shore, and in Great Britain always returns with the tide, when it ventures up rivers. When kept in salt-water ponds the fish become so tame as to assemble at a signal given them. When enclosed in the seine net the Grey Mullet often leaps over the head line, and is followed by all its associates, in the same way that Sheep follow their bell wether. They feed on soft and fat food, especially such as is slightly decayed. In Guernsey the Mullet has been kept in fresh-water ponds, and found to improve in weight even more rapidly than the other sea fishes which have been experimented upon in the same way. The colour upon the top of the head and back is greyish-blue, while the sides and belly are silvery, with parallel dusky lines running along the length. The *Mugil septentrionalis* is found on the British and Scandinavian coasts, and reaches a length of twenty-three inches. A third British species (*Mugil curtus*) is occasionally captured in the English Channel.

The twelfth division is the Gasterosteiformes, a small group of fishes comprising the Sticklebacks and the Pipe-fishes of the family Fistulariæ.

FAMILY XLIV.—GASTEROSTEIDÆ.

The Sticklebacks all belong to the genus *Gasterosteus*, of which eleven species and several varieties are known. These are small fishes of elegant form, mostly limited to fresh or brackish water.



TEN-SPINED STICKLEBACKS.



FIFTEEN-SPINED STICKLEBACK.

In Great Britain there are two fresh-water species, the Three-spined Stickleback and the Tinker, or Ten-spined Stickleback, and one marine species, the Fifteen-spined Stickleback.

The Three-spined Stickleback (*Gasterosteus aculeatus*) is so named from having three spines in the middle of the back, in the position usually occupied by the first dorsal fin. The body is moderately elongated and compressed; the ventral fins have one strong spine; the middle of the body is covered with plates, but there are no scales. It is a furious fighter, but, as is so often the case in the animal kingdom, the females are peaceful, and it is only the males who do battle. These fishes are remarkable for their parental instinct, which leads the male to build a nest and watch carefully over the young. The nest is made of stalks of grass and other substances, which are cemented together with mucus, either from the mouth or from the skin. The bottom of the nest is first laid, and afterwards the sides and top are built. According to Signor Costa, as quoted by Yarrell, a small hole is left on one side of the nest. The colours of the male now become extremely brilliant. After a good deal of coaxing he drives the female into the nest. She makes her way out on the opposite side of the nest to that by which she entered, leaving the eggs behind. The male fertilises the eggs, and is said to frequently bring to the nest a succession of females. He then watches for a month over the nest, which is about the size of a shilling, or a little larger, and is placed at the bottom of the stream in about six inches of water. The eggs are of a bright yellow colour. The length of this species rarely exceeds three inches. In some parts of the country, when abundant, the fish have been collected for manure. They live from two to three years. Yarrell mentions that in Kamschatka and Rupert's Land they are stored as winter food for dogs, that hogs

are sometimes fed on them, that oil is extracted from them in Eastern Russia, and they are sometimes made into fish soup.

The Ten-spined Stickleback (*Gasterosteus pungitius*) has the row of dorsal spines much lower than in the foregoing species. There are no plates on the sides of the body in this species. The male at the breeding-time becomes velvety-black. The nest of this Stickleback is built upon aquatic plants, or among their roots, and has been compared to the nest of a Wren.

The Fifteen-spined Stickleback, or Sea Adder (*Gasterosteus spinichia*), is a marine species, five to seven inches long, which never ascends rivers, and makes its nest of seaweed or coralline, and guards the eggs like the fresh-water species. It has the same rapacious habits, and feeds on the eggs and fry of fishes, worms, and other marine animals. Mr. Richard Q. Couch carefully watched the method of nest-making, and found that the materials were bound together with an elastic thread, which resembled silk, which hardens by exposure to the water, and is seen under a magnifier to consist of several smaller threads united together; but the way in which it is secreted has not been determined. The eggs are a bright amber colour. Couch records that on one occasion a nest as large as the fist had been built in the hollow formed by the untwisted strands of a rope which hung in the sea. The embryo when first hatched is unlike the parent, the head being round and blunt instead of elongated, and the pectoral fins are relatively large, while the dorsal and anal fins extend along the body to unite with the caudal fins. The ventral fins are at first absent. The colour of the fish is variable, sometimes reddish-brown, sometimes dark green. It is met with on all the northern coasts of Europe.

FAMILY XLV.—FISTULARIDÆ.

The Fistulariæ are fishes having a greatly elongated body, and the head is even longer than in the Fifteen-spined Stickleback. In the Stickleback family the ventral fin is joined to the pubic bone, but in the Fistulariæ these fins are remote from the pubic bones. In the genus *Fistularia* the body is without scales, has no free dorsal spines, has the caudal fin forked with the two middle rays prolonged into a filament. There are only two species of *Fistularia* known—the *Fistularia tabaccaria* and *Fistularia serrata*. The head is a long depressed tube, one-third of the total length of the body; there are bony shields immediately below the skin protecting the anterior part of the trunk. The lateral line runs along the length of the dorsal shield, and then bends downward to the middle of the side. There are four vertebrae united together in the neck into a solid mass, forty-nine vertebrae in the abdomen, and thirty-three in the tail. There are no ribs. The teeth are small, and occur on the jaws, palatine bones, and vomer. The *Fistularia tabaccaria* is from the tropical parts of the Atlantic and Indian Oceans; the *Fistularia serrata* ranges from the coast of Mozambique to China and Australia.

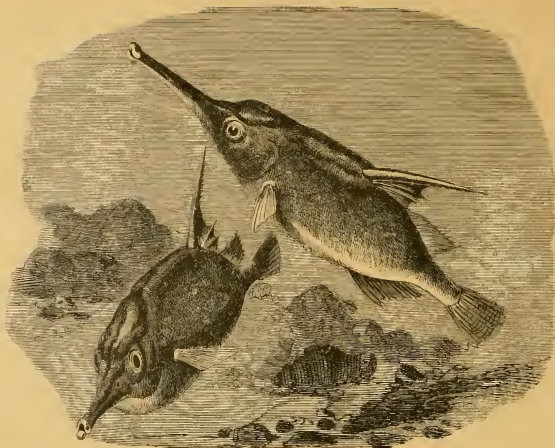
The second genus of this family—*Aulostoma*—has the body covered with small scales, has a series of feeble isolated dorsal spines, wants the filaments to the tail, and has rudimentary teeth. One species is from the Caribbean Sea, the other ranges from the coast of Mozambique to the Western Pacific. The neck vertebrae are blended together as in *Fistularia*.

The thirteenth division is named *Centrisciformes*, a family comprising two genera.

FAMILY XLVI.—CENTRISCIDÆ.

The genus *Centriscus* has the body scaly, or covered with prickles, and the genus *Amphisila* is without scales, but has a bony cuirass, which is attached to the spine of the first dorsal vertebrae.

The species of the genus *Centriscus* frequent Australia, China, and the southern part of Europe and the Mediterranean. The *Centriscus scolopax*, which reaches the south coast of England, is known as the Trumpet-fish, or Bellows-fish. Some authors have termed it the Sea Snipe. The body is compressed and oblong, with the snout prolonged like a tube, which terminates in a narrow toothless mouth. There are two small dorsal fins placed far back. The second spine of the first dorsal fin is long, very strong, and has its hinder border serrated. The body is covered with small spiny scales; there is no lateral line. There are several bony plates on the back and abdomen; the ventral fins are as close together as in the Gobies, and they are received into a groove on the belly. There are eight vertebrae in the abdomen, which are strong and large, and the transverse processes



TRUMPET-FISH OR BELLOWS-FISH.

of the first four have their extremities united. The colour of the fish is a rose or reddish-green on the back and silvery on the belly. The flesh of this species is eaten, and considered to be good. Dr. Günther remarks that the allied genus *Amphisila* may be considered as a Chelonian form among fishes.

The fourteenth division, *Gobiesociformes*, includes two families of naked fishes which have no spinous dorsal fin.

FAMILY XLVII.—GOBIESOCIDÆ.

The *Gobiesocidæ* have an adhesive sucker between the ventral fins, and the *Psychrolutidæ* have no ventral fins. The family *Gobiesocidæ* comprises nine genera, and though the sucker is similarly placed to the sucker of the *Discoboli*, its structure is different. In those fishes the ventral fins occupy the centre of the disc and form its base, but in these the fins are widely separated from each other, and only margin the disc, which is about one-third of the whole length of the fish, and has its border chiefly formed by cartilaginous expansions of the coracoid bones. Dr. Günther remarks that the posterior or coracoid portion has the skin divided into many polygonal plates, which are wanting in the anterior part which lies between the roots of the ventral fins. The genera are widely distributed; *Chorisochismus* is from the Cape Sea, *Sicyases* from the coast of Chili, *Gobiesox* from the Caribbean Sea and west coast of South America, *Crepidogaster* from the coasts of Australia, while *Lepadogaster* is found in the Mediterranean, and ranges northward to the Scandinavian coast. Of this genus there are three British species—*Lepadogaster gouanii*, usually known as the Cornish Sucker, the *Lepadogaster candollei*, or Connemara Sucker, and *Lepadogaster bimaculatus*. These are small fishes, varying from an inch to three inches in length. In the Cornish Suckers the vertical fins are continuous with the caudal fin, but in the *Bimaculate* Sucker the vertical fins do not reach so far back. The colour is usually more or less red, but is variable. In all these fishes the intestine is short, straight, and wide.

FAMILY XLVIII.—THE PSYCHROLUTIDÆ.

The *Psychrolutes paradoxus*, from Vancouver Island, is the only fish in the Psychrolutidæ, a family which unites many characters of other families which have been here described.

The fifteenth division of the order is the Channiformes, an interesting group of two genera of fresh-water fishes from the East Indies. Some species are limited to India, Siam, and China; other species are found in the rivers of Sumatra and Borneo.

FAMILY XLIX.—THE OPHIOCEPHALIDÆ.

The Walking-fish (*Ophiocephalus*) has the body long and nearly cylindrical in front. The flattened head is covered with shields above, and the body with scales of moderate size. There are fine teeth on the jaws, vomer, and palatine bones, suitable for grasping the many small land animals which fall a prey to these fishes. There is a cavity connected with the gill-chamber which retains water so as to moisten the gills, but there is no distinct organ for this purpose, such as is found in the Climbing Perch. These fishes become buried in the mud when the pools dry up, and are often found in India by digging at a depth of two or more feet below the dry surface. There are fifty-one vertebrae in the abdomen and sixty-one in the tail. There is one long dorsal fin, but both it and the anal fin are without spines. *Ophiocephalus* possesses ventral fins, but in the genus *Channa*, from the fresh waters of Ceylon, the ventral fins are absent. The



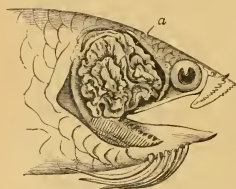
CLIMBING PERCH.

Ophiocephalus striatus is taken by the native fishermen with a long flexible bamboo as a rod, and a hook baited with a live frog, but these fishes are also often captured with nets. They are monogamous, and universally distributed over India. The *Ophiocephalus* breeds twice a year, in June and December. The male then bites off the ends of water-weeds and constructs a nest with his tail amongst the vegetation. After the ova are deposited the male keeps guard over them, but his place is taken by the female if he should happen to be killed. After the young are hatched they swim a little above their parents, who defend them with great courage. None of the fishes of this family migrate. The species of *Ophiocephalus* are most successfully carried from place to place in mud, but they need when in water to rise to the surface to breathe air. According to Mr. Day, they are often captured in Burmah by spreading a large cloth over the mud in which they have buried themselves, when they soon become stupefied from deficiency of oxygen. *Ophiocephalus* falls a prey to fresh-water Snakes, the fresh-water Porpoise, and the fish-eating Crocodile (*Gavialis gangeticus*).

FAMILY L.—THE LABYRINTHICIL

The sixteenth division, termed the Labyrinthibranchii, contains two families. This family includes nine genera. The fishes have the body covered with scales of moderate size, which also extend over

the head. The gill-opening is rather narrow, and there is an organ above the cavity of the gills which is formed of thin bony laminae, which branch and are folded so as to somewhat resemble a compound coral. This organ is placed upon the upper part of the first branchial arch, and retains a small quantity of water, which serves to moisten the gills. The fish are capable of living for some time out of water or buried in mud. Several of the species have been domesticated, and they are carried about by the Indian jugglers with their other apparatus. The various species live on small animals as well as upon vegetable substances, and have been said to mount trees to a height of several feet from the ground. One of the best known genera is *Anabas*, commonly called the Climbing Perch. The supra-branchial organ becomes more complicated as the fish increases in



SUPRA-BRANCHIAL ORGAN (a) OF THE CLIMBING PERCH.

size. The length of *Anabas scandens* is generally about seven inches. It has teeth in the jaws and on the vomer. There are many spines in the dorsal fin and several in the fore part of the anal fin. The opercular bones are serrated, the air-bladder is divided posteriorly, and both portions extend to near the end of the tail. This species is of a greyish-olive colour, and is found throughout the East Indies in rivers and estuaries. Natives while fishing, according to Day, kill the Climbing Perch by biting through the vertebral column behind the head, but in this operation the fish occasionally slips down the throat, and then, owing to its spiny character, it can be withdrawn only with great difficulty. Other species occur in China and the Malay Islands. The genus *Helostoma*, which has the air-bladder simple, is confined to Java. *Polyacanthus*,

like the foregoing genus, has no spines on the operculum. *Macropus* is a genus domesticated in China. The Gourami (*Osphromenus olfax*) is a nest-building fish of this group, with the first ray of the ventral fin greatly elongated. It is found in the fresh waters of Java, Sumatra, and Borneo. The genus *Spirobranchus* occurs in the rivers of the Cape of Good Hope. The genus *Ctenopoma* is found near the mouth of the Zambesi in pools. Many of these fishes have colours of dazzling beauty, and some of them are highly valued for food.

FAMILY LI.—THE LUCIOCEPHALIDÆ.

Luciocephalus pulcher has a broad black band, margined below with white, running from the eye to the caudal fin, and often has round black spots on the fins and body. It occurs in the fresh waters of Borneo and some of the adjacent islands, and is the only member of its family which differs from the foregoing by having no spines in the anal fin or short dorsal fin, and by having the gill-opening wide.

The next division differs from all the foregoing in having the vent placed in front of the ventral fins.

FAMILY LII.—THE APHREDODERIDÆ.

This family includes only one species (*Aphredoderus sayanus*), which is found in many of the lakes and streams of the Atlantic coast of North America. The ventral fins are placed in the thoracic region: there is one dorsal fin, but its spinous part is but little developed.

FAMILY LIII.—THE LOPHOTIDÆ.

The eighteenth division also includes only one family, which is represented by *Lophotes cepedianus*, a fish with a riband-shaped body, with the vent near the extremity of the body, and a short anal fin behind the vent. One dorsal fin runs the whole length of the back; there are no scales. The head is elevated into a high crest; the fins are rose-coloured, but the body is silvery. It reaches a length of about five feet, and is found in the Mediterranean and the Sea of Japan.

The nineteenth division includes only

FAMILY LIV.—THE TRACHYPTERIDÆ.

These fishes have the skeleton soft, and the body elongated, strongly compressed, and without scales. The dorsal fin extends the whole length of the back, and has a detached anterior part. The anal

fin is always wanting; the caudal fin is usually directed upward. All the species frequent deep seas. Three genera have been defined. The genus *Trachipterus*, which has well-developed ventral fins, is represented by many species on the Mediterranean coasts of Europe, and also occurs on the west coast of South America. In British waters it is represented by the Deal-fish (*Trachipterus arcticus*), which ranges northward to Iceland and Norway. Large specimens are six feet long and one foot high. Its body is very tender and brittle, so that it is rarely preserved. Its movements are slow, and resemble those of the Flat-fish. They are said when alive to be fat, with the sides of the body round. The sides are silvery, the high dorsal fin is red, and the caudal fin, which is directed upwards like a cock's tail, is also red. The genus *Stylophorus*, found in the Gulf of Mexico, has the tail terminated in an appendage like a cord, which is twice as long as the fish's body. The genus *Regalecus* has each ventral fin reduced to one long filament, and the caudal fin is usually absent or represented by a rudiment. Two species occur in the Mediterranean, two on the coast of Norway, while one, known as the Ribbon-fish, or Oar-fish (*Regalecus banksii*), occurs in British seas. A specimen was taken in Yorkshire twenty-four feet long, though the usual length is about twelve feet. The colour is silvery, with irregular dark lines and spots on the anterior part of the body. The dorsal fin is red, but there is no trace of a caudal fin. The anterior twelve spines form an elevated crest behind the head. The lateral line is marked on the lower third of the body by elongated flat scales, but the skin generally is covered over with small bony tubercles. The snout is truncated, and there are no teeth in the mouth. The stomach is prolonged as a pouch, which reaches between the muscles to near the end of the tail. A specimen measuring fifteen feet and a half in length was one foot two inches deep, three inches and a half thick, and weighed 182 lbs.

The twentieth and last division of Acanthopterygian fishes is formed for

FAMILY LV.—THE NOTACANTHI.

This family includes the species of the genus *Notacanthus*. This group is characterised by having the dorsal fin represented by short free spines, the soft portion being sometimes entirely absent. The snout protrudes beyond the mouth. Species occur in the Mediterranean, Arctic regions, and in the Australian seas. The *Notacanthus rissouanus*, which has the nasal region prolonged into a proboscis, and has thirty or more spinous finlets on the back, is regarded by Dr. Günther as likely to form the type of a second genus.

CHAPTER VI.

THE ORDER PHYSOSTOMI.

ORDER PHYSOSTOMI—SILURIDÆ—Characters—The Various Sub-Families—The Silurus glanis—The Malapterurus electricus—Its Electric Organ—The Genus Loricaria—Curious Feature connected with the Genus Aspredo—CHARACINIDÆ—HAPLOCHITONIDÆ—STERNOPYGIDÆ—Pearl-spotted Fishes—SCOPELIDÆ—Bombay Duck—STOMIATIDÆ—SALMONIDÆ—Characters—THE SALMON—Description—Climbing the Rivers—The "Leaps"—Changed Appearance after Spawning—Hatching—The Fry—Growth—Stages of the Young—The Journey to the Sea—The Salmon at Sea—Various Modes of Fishing—Largest Catches—Distribution—THE GREY TROUT—THE SALMON TROUT—THE COMMON TROUT—THE GREAT LAKE TROUT—Other Species of Trout—THE CHARR—Various Species—THE SMELT—THE CAPELAN—The Genus Coregonus—THE POLLAN—THE GRAYLING—PERCOPSIDÆ—GALAXIDÆ—MORMYRIDÆ—GYMNARCHIDÆ—ESOCIDÆ—THE PIKE—Its Size and Age—Its Voracity—Pike Migrations—The Lucie Family—Characters of the Fish—UMBRIDÆ—SCOMBRESOCIDÆ—The Genus Belone—The Garfish—The Genus Scombrox—The Saury, or Skipper—The Genus Hemiramphus—The Flying Fish—The Genus Exocoetus—Characters—Height and Duration of Flight—CYPRINODONTIDÆ—Singular Eye Character of Anableps—HETEROPTYCH—CYPRINIDÆ—Distinctive Features—The Carp—Habits—Carp Culture—Its Diet—The Crucian Carp—THE GOLD FISH—Kept as a Pet—Variation in Colour—Characters—The Barbel—The Gudgeon—The Roach—The Chub—The Dace—The Ide—The Red-eye, or Rudd—The Minnow—The Red-fin—The Spawn-eater—The Tench—The Rhodeus amarus—The Bream—The Bleak—The "Essence de l'Orient"—The Loach—The Spinous Loach.

ORDER VI.—PHYSOSTOMI, OR FISHES WITH THE AIR-BLADDER OPENING INTO THE MOUTH.

THE Physostomi form a large division of fishes characterised by having the fin rays jointed. Sometimes, however, the first ray in the dorsal fin and in the pectoral fin are more strongly developed

than the others, and more or less ossified. The spines are never found in the ventral fins, but these fins are sometimes absent, and when present are placed in the abdominal region of the body. When the air-bladder exists it is always connected with the throat by a pneumatic duct.

This order of fishes includes, in Dr. Günther's classification, twenty-nine families. It comprises a vast multitude of genera, the Siluroid family alone including nearly 120 generic types, while among the other families are such familiar fishes as the Eels, Conger Eels, Herrings, Salmon, Pike, and Carp.

FAMILY L.—SILURIDÆ.

The Siluroid fishes never have scales, and when the skin is not naked it bears on its surface bony plates or scutes. The maxillary bones are here reduced to rudiments, and generally form the support for a maxillary barbel, so that the margin of the upper jaw is formed by the pre-maxillary bones only. The operculum is peculiar in wanting the sub-opercular bone. The air-bladder communicates with the organ of hearing by means of auditory ossicles. The dorsal and anal fins are variable in their development, and the characters from these organs, together with the positions of the nostril and of the vent, are used to subdivide the family into great groups, which Dr. Günther names Homaloptere, Heteroptere, Anomaloptere, Proteroptere, Stenobranchiæ, Proteropodes, Opisthoptere, and Branchicolæ. Each of these sub-families is again subdivided according to the characters of the gill membranes, nostrils, lips, barbels, and positions of the fins.

The Siluroid fishes are found in the fresh waters of tropical and temperate regions, and the few which enter the sea keep near to the coast. The genus *Clarias* has one group of species confined to Africa and Syria, distinguished by having a prominent occipital crest which is angular behind, while in East Indian species that prominence is less developed. The best-known species is *Clarias anguillaris*, a fish eighteen inches long, from the Nile and West Africa. Two species from the Ganges and East Indian Archipelago have the caudal fin united with the dorsal and anal fins. As the waters dry up, these fishes make their way over the mud by help of their fins in search of water, and at the time of these migrations are readily captured. *Heterobranchius* is an allied genus distinguished by having two dorsal fins, the anterior supported by rays, and the posterior fatty. Its distribution is chiefly African, but one species—*Heterobranchius tapeinopterus*—has been found in Borneo and Banka. The number of barbels in these fishes is usually eight—two pairs on the mandibles, one pair of maxillary barbels, and a nasal pair. The species of the genus *Cnidogobius* are confined to the rivers and coasts of Australia; in them the second dorsal fin is long, and is continuous with the caudal and anal fins. In the genus *Chaca* there are no barbels on the nostrils, and the eyes are rudimentary. The species are East Indian.

The only representative of the Siluroid family in Europe is the *Silurus glanis*, which occurs in the rivers of Europe east of the Rhine. It is the largest of European fresh-water fishes, and is said to have once been captured in a tributary of the Shannon. It is absent from Britain, France, Spain, and Italy. It was formerly taken in Haarlem Meer, is rare in Scandinavia, common in Prussia, Poland, Styria, the Danube, and the rivers of Southern Russia. In the river Bug it has been taken sixteen feet long. Quoting from Valenciennes, Yarrell states that a specimen captured near Thorn had the entire body of an infant in its stomach; and another example taken in Hungary is said to have contained the body of a woman having a marriage ring on her finger and a purse full of money at her girdle. Young specimens are valued for food, but are not easily captured. It is commonly found at the bottom, but rises to the surface in stormy weather.

The fat is used in dressing leather, and the air-bladder is made into gelatine. There is one small dorsal fin in this genus conspicuous for wanting the anterior spine. The anal fin, however, is well developed, and extends back, so as to unite with the caudal fin, which is rounded.

The head and body are covered with soft skin, and the colour is a mottled brownish-olive. The pectoral fin has a stout spine for its first ray, and this is slightly serrated at the free end. The vent is placed behind the ventral fins. There are four barbels on the mandible, and one, greatly elongated, is attached to each maxillary bone.

Other species of *Silurus* occur in Afghanistan, Cochin China, Malabar, China, Japan, and Formosa. The genera allied to *Silurus*, which form Dr. Günther's second sub-family, or *Heteroptera*, are all confined to the Old World. The third sub-family is South American. The genus *Helogenes* has the eye very small, and covered over with the skin, as is the case in several other Siluroid fishes. *Hypophthalmus* has the eye behind, and below the angle of the mouth; the mouth is devoid of teeth.

The genus *Amiurus* is confined to North America, though one species ranges to China. The palate is toothless, and there are only eight rays in the ventral fin. Many genera of Siluroid fishes are covered in the region in front of the dorsal spine with heavy armour, which frequently has a granulated surface. This armour is well seen in the genus *Rita*, in *Elurichthys*



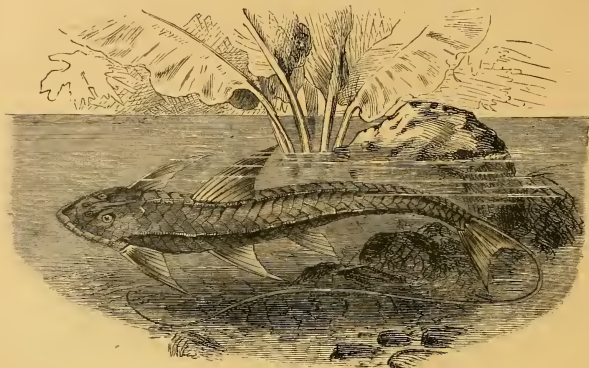
MALAPTERURUS ELECTRICUS.

nuchalis, and in the genus *Doras*, which has a series of about twenty lateral shields on each side of the body, each with a prominent spine in the centre. There are also broad dermal plates on the neck. All the species of the genus *Doras* occur in South American rivers which flow into the Atlantic. Similar lateral plates characterise the genera *Oxydoras* and *Rhinodoras*, which have a like distribution. The African genus *Synodontis* has broad dermal bones on the neck. The genus *Rhinoglanis* is a small fish an inch and a half long, from Gondokoro, on the Upper Nile, which has two dorsal fins, both formed of rays. It has six barbels, the two longest ones, from the maxillary, reach to the origin of the second dorsal fin. The whole of the neck is covered with a cuirass formed of three broad plates. The tail is forked.

The electric Siluroid, *Malapterurus electricus*, is found in the Nile and the rivers on the West coast of Africa. Its single dorsal fin is fatty, and placed in front of the caudal fin, which is rounded. The pectoral fins want the strong, sharp spines which are so characteristic of most fishes in this family. The body is covered with more or less small round black spots, and the anal and caudal fins are margined with white. The electric organ extends over the whole

body, and is placed below the external skin. There are two other species of this genus from Old Calabar, but neither of these possesses the electric organs. Even the electric species is dangerous to small animals only. Its flesh is eaten, and the electric organ is esteemed by the natives for its supposed healing properties, which, however, are developed by burning the tissue and allowing the patient to inhale the fumes. The next group includes genera, in which the body is more or less completely contained in bony armour. The males of the genus *Callichthys* have the spines in the pectoral fins stronger and longer than those of the female, the spine increasing in size as the male reaches maturity, and it is also noticed that the thoracic plates are much larger in old males than in females. The species are characteristic of the rivers of tropical America and Trinidad. *Callichthys barbatus* has the end of the snout armed with stiff bristles, and there are two rows of lateral shields along each side, but behind the dorsal fin the shields of the two sides join each other.

Several species of *Plecostomus*, another genus from tropical America, have the snout armed



LORICARIA CATAPHRACTA.

with bristles. The genus *Chaetostomus* is remarkable for having the inter-operculum movable, and armed with a bundle of erectile spines, which are long and bristle-like. The number of spines varies in the different species, which are all from the tropical part of South America, except *Chaetostomus trinitatis*, from Trinidad and *Chaetostomus guacharoto*, from Porto Rico.

Similar spines characterise the Brazilian genera *Pterygoplichthys* and *Acanthicus*. The genus *Loricaria*, from the fresh waters of South America, has the snout more or less elongated beyond the mouth, with a short barbel at each corner of the mouth. The small bent teeth when present have the apex expanded and notched. The tail is long, and flattened, and both head and body are encased in armour. In the *Loricaria cataphracta*, from Surinam and Northern Brazil, the upper ray of the caudal fin is produced into an immensely long filament, a character also seen in the *Loricaria vetula* from the Rio de la Plata, and in several other species. There are eight or ten lateral scutes between the pectoral and ventral fins, and the belly and thorax are defended with numerous small and irregular scutes. The outer ray of the pectoral fin is about one-sixth the length of the body. The *Loricaria barbata* has the sides of the head armed with erectile bristles. Most of the species have the snout broad, but in some it is long and narrow. The *Loricaria acipenserina* has the snout terminating in a spiny knob, and the long snout of

Loricaria depressa is turned slightly upward. Some species of this genus have been observed lying on the sand fully a yard from the water.

The genus *Aspredo*, the type of Dr. Günther's fourteenth group of Siluroid fishes, is chiefly remarkable for the care which the females take of their young. Dr. Günther remarks that the whole of the lower surface of the belly, throat, thorax, and a part of the pectoral fins in *Aspredo batrachus*, shows numerous shallow round impressions to which the ova are often found adhering. The eggs are spread out in a single layer, so as to leave small interspaces between them, which are occupied by short soft appendages to the belly, each of which expands at its free end into a disc, and these bodies help to keep the ova in position. Dr. Günther thinks it probable that towards spawning time the skin of the lower part of the body becomes spongy, and that after the eggs are deposited, the female lies on them so as to attach them to her body, and that in consequence the spongy substance is absorbed where the eggs press so as to leave the disc-like filaments of the spongy tissue in the interspaces between them. After the eggs are hatched the excrescences disappear and the belly becomes smooth. This genus has no adipose fin, and no strong spine to the short dorsal fin. The anal fin is very long. The gill-opening is a narrow foramen in front of the strong pectoral spine, which is denticulated. The species of this genus are found in British, Dutch, and French Guiana. Some species of the genus *Trichomycterus* ascend streams in the Andes to an elevation of fifteen thousand feet. The greater number of the South American Siluroids are small fishes.

FAMILY II.—CHARACINIDÆ.

The Characinidæ are distinguished from the Siluroids by having the head naked, and free from barbels, while the body is covered with scales. The maxillary bones form the lateral margins of the upper jaw. The air-bladder is divided transversely into two parts, and is connected with the organ of hearing by auditory ossicles. There are nearly fifty genera in this family, all of which inhabit the fresh waters of tropical Africa and America. In five of the genera allied to *Macrodon* there is no adipose fin, but in all the other types the adipose fin is present. Some specimens of *Macrodon trahira* have the tongue smooth, while others show upon it large patches of prickles. The *Macrodon aimara*, from Cayenne, has very large canine teeth. In the genus *Erythrinus* the anterior part of the hinder air-bladder has a cellular structure. All the species are from tropical America. The air-bladder presents similar characters in the *Lebiasina bimaculata* from Peru and Ecuador. The species of the genus *Prochilodus* which inhabit various parts of South America eat mud, and are remarkable for the great length of the intestine, which is coiled round many times. Great length of the intestine also characterises several other genera in this family, in which the teeth are either absent or extremely small. The nostrils vary in position a good deal in the allied genera, and are commonly more or less distant from each other, but in *Tetragonopterus*, a tropical American genus, they are close together, and separated only by a valve. In the genus *Brycon*, which is found in the east of the Andes, the pre-maxillary bone is armed with three series of teeth, which, like those in the mandible, are notched so as to have three cusps, a character also seen in the genus *Chalcinopsis*. The lateral line is sometimes absent and sometimes well marked in these fishes; in the Brazilian genus *Gastrolepis* it descends obliquely towards the origin of the anal fin. In the *Anacyrtus gibbosus* the two rows of teeth on the pre-maxillary bone are almost confluent into one. The *Anacyrtus microlepis* of Brazil has short conical processes like teeth directed outward in both the upper and lower jaws. Some genera, like *Xiphostoma*, have the snout elongated and conical, the prolongation being formed by a cartilaginous appendage.

FAMILY III.—HAPLOCHITONIDÆ.

This family includes two fresh-water genera, which, according to Dr. Günther, represent the Salmon. *Haplochiton*, from Tierra del Fuego and the Falkland Islands, has the simple air-bladder united to the thick and muscular stomach. A broad tongue carries a series of curved teeth on each side. The ovaries are in layers, and allow the eggs to fall into the cavity of the abdomen, there being no oviduct. The other genus, *Prototroctes*, is limited to South Australia.

FAMILY IV.—STERNOPTYCHIDÆ.

The Sternoptychidæ include six genera, four of which are naked, while the other two have the body covered with deciduous scales; both the maxillary and pre-maxillary bones bear teeth. The

genus *Argyrolepecus* includes several deep-sea fishes from the Atlantic and Mediterranean, which have the body covered with silvery pigment, while a series of phosphorescent spots runs along the lower side of the head, body, and tail; a series of imbricated scutes extends from the humeral arch to the pubic spine. A similar series of twenty-five luminous spots marks the body of *Coccia ovata*; they are small pearl-coloured discs, each mounted on a black globular body. The stomach in this fish is remarkable for having two elongated branches, one of which is directed backwards, while the other runs forward. This group of fishes is represented on British shores by the Pearl-side, *Mauroliscus borealis*, a small fish varying from an inch to two inches and a half long. Its sides have a resplendent silvery lustre, and on each side there are about forty-six or forty-seven pearly spots, placed in depressions in the skin, each margined with a narrow black ring. In front of the ventral fin, there are twenty-four spots on each side, extending backward from the head in two parallel rows placed low down on the side. There is a short single row extending in a curve between the ventral fin and the beginning of the anal fin, while from the commencement of the anal fin to the caudal fin the spots are so close together as to be almost confluent. It occurs throughout the North Atlantic, but most of the English specimens have been cast on shore at Redcar.

In the Mediterranean other species are met with, in two of which there are from twenty-three to twenty-five pairs of luminous spots on each side, which Dr. Günther describes as resembling convex pearls, each resting upon a black globe-shaped body. The two genera of this family, *Gonostoma* and *Chauliodus*, which have thin deciduous scales, both have series of luminous spots running from the lower side of the head to the tail. They are represented by single species, which occur in the Mediterranean.

FAMILY V.—SCOPELIDÆ.

This family comprises many genera of fishes which frequent the open sea, or are found in deep water. They differ from each other in the length and position of the dorsal fin, the characters of the teeth, and presence or absence of scales. The *Harpodon nehereus* has been called the Bombay Duck. It is well known in England as an article of food when imported dried. Its vertebrae are soft, and perforated by a channel which is occupied by the unossified remains of the notochord. It occurs in the Ganges and throughout the Indian and Chinese seas. Two genera, *Scopelus* and *Scopelosaurus*, have series of luminous spots which run down the sides of the head, body, and tail, and in the former genus a similar substance sometimes covers the front of the snout and the back of the tail. The species of *Scopelus* are chiefly found in the open waters of the Mediterranean and Atlantic, though *Scopelus boëps*, *S. asper*, and *S. sub-asper* are found in the Pacific. The species are all small, varying from one inch to ten inches in length. The genus *Alepidosaurus* is constituted for long compressed fishes which are without scales. They are extremely fragile, and the connection between the vertebrae is so loose, that the length of the fish is easily stretched. *Alepidosaurus ferox*, which inhabits the deep sea of Van Diemen's Land and of the Atlantic, is ferocious. The stomach of one specimen caught at Madeira contained a young individual of its own species, one *Trachurus trachurus*, twelve young *Capros aper*, one young *Brama*, and several Octopods, Crustaceans, and Ascidians. All the bones are flexible, and contain very little earthy matter. The vertebral column includes forty-two long vertebrae. Dr. Günther records that this fish has a system of abdominal ribs arranged symmetrically on both sides. They run the whole length of the median line of the abdomen to the origin of the anal fin.

FAMILY VI.—STOMIATIDÆ.

This family is a small group of fishes found only in the Atlantic, and usually in deep water. Three of the genera, *Astronesthes*, *Echiostoma*, and *Stomias*, have series of phosphorescent dots along the lower side of the head, body, and tail. The two first-named genera have the body naked, and *Stomias* is covered with delicate deciduous scales. *Astronesthes niger* has the body of a brownish-black colour, and has two dorsal fins, the second one being formed of fat, as is usual in this order. The other genera have but one dorsal fin, which is placed opposite to the anal fin. All these fishes have a fleshy barbel suspended from the centre of the hyoid region.

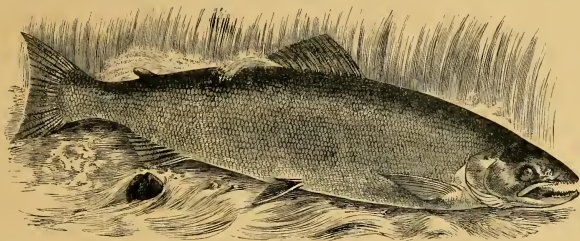
FAMILY VII.—SALMONIDÆ.

The Salmonidæ include fifteen or more genera, all of which are covered with scales, though in the Japanese Whitebait of the genus *Salanx* the scales are very delicate and deciduous. The head, however,

is naked in the whole family. The maxillary bones form the sides of the jaws. There is always a small fatty fin behind the dorsal fin. The air-bladder is large and simple. The eggs fall into the abdominal cavity before they are deposited. These fishes are chiefly found in the fresh waters of the temperate and arctic regions of the northern hemisphere, though the genera *Argentina* and *Microstoma* are marine, and never enter rivers; and the New Zealand Smelt (*Retropinna richardsonii*) is found only in the rivers of New Zealand.

THE SALMON.*

In the summer the Salmon is caught in the estuaries of British rivers. Its form is too well known to need detailed description. The belly is silvery-white, as is the anal fin and the outer side of the ventral fin, the under side of which is dusky, and approaches in colour to the dusky black of the caudal, dorsal, and pectoral fins. The head in its upper part and the back are of a bluish-black colour. Often there are a few dark spots extending over the body above the lateral line, and they are commonly more numerous in the female than in the male. Low down on the back, just behind the anal fin, is a small second dorsal fin, formed chiefly of fat, and unsupported by bony rays. The first dorsal fin, in which the rays are strong, is placed about the middle of



SALMON.

the length of the body, nearer to the head than the tail, and the ventral fin is situate somewhat laterally below its middle or hinder part. In the mouth, teeth occur on all the maxillary bones, but in the upper jaw they also extend in the median line on the bone, called the vomer, and form an arch on the palatine bone. There are usually twelve bony rays for the support of the gills, but the number varies. The form of the operculum is one of the best characters for distinguishing the Common Salmon from the species to which it is allied, for its posterior outline is part of a circle. The scales are very small. There are 120 in the lateral line, 25 rows above it, and 18 below. There are about sixty vertebrae in the skeleton. The appendages to the commencement of the intestine, which represent the pancreas, number from sixty-three to sixty-eight. Salmon come up from the sea to spawn in rivers at various periods during the spring and summer. It has been observed that the fish are always late in going up those rivers which become muddy and swollen in the spring by the melting of snow on the mountains, but that rivers which have deposited their sediment in lakes, and thus become limpid, furnish the earliest supply of Salmon. Yarrell has drawn attention to the fact that in early spring all the Salmon which enter the river Oykill, in Sutherlandshire, diverge at about five miles from its mouth into its tributary, called the Shin, which rises in a large and deep loch, where, owing to the mass of water, the temperature is warmer, while later in the season the Salmon pass on up the main course of the Oykill, which has then become warmer.

It has also been noticed that in Cumberland the fish prefer the river Eden to the Esk, though both rivers empty into the same estuary. The Salmon ascend the river with the flood, and generally retire with the ebb of the tide. The female fishes appear before the

* *Salmo salar*.

males, and the young, on their first return from the sea, advance up the stream earlier than the old Salmon. As time goes on they ascend beyond the reach of the tide, and shoot up rapids and small cascades, often clearing a height of eight or ten feet at a bound. In Scotland they frequently kill themselves by their violent efforts to ascend streams in which there are natural obstacles. The limit of their perpendicular spring is about twelve or fourteen feet; hence ladders and staircases have been invented to enable the fish to overcome difficult rapids. When the animal has at last reached the upper and shallow pools of the river, and the spawn is deposited in the gravelly beds, the external appearance undergoes some singular changes, for in the male the lower jaw elongates and curves up over the snout, the skin thickens on the back and fins, the body acquires a golden orange tinge, and orange-coloured stripes appear on the cheeks; but the females grow darker in colour, and are spoken of as black fish, just as the males are called red fish. When spawning commences, a pair of fish working against the stream are said by some observers to make a furrow in the gravel with their noses, while others say the furrow is made with the tail. The furrow made, the male and female place themselves on each side of it. It is affirmed that they then throw themselves together on their sides, and, rubbing against each other, shed their spawn simultaneously into the furrow. This process is continued for about eight or twelve days, until all the spawn is laid, after which the fish retire to the pools to recruit their exhausted energies.

After the eggs are deposited they are covered with gravel. Eggs that were observed to be deposited in the Tweed on the 2nd of November were found on the 23rd of March to be hatching; the fry, however, less than an inch long, were lying embedded in the gravel; but a week later, Dr. Knox found that most of the young had escaped from the gravel where the eggs had lain for twenty-one weeks. Eggs laid in the autumn are generally hatched in ninety days.

The time required to hatch the Salmon is governed chiefly by the temperature of the water. The earliest experiments in hatching the fish artificially were made by Mr. Shaw, who records that the young are at first nearly transparent, with a continuous fin round the hinder part of the body, and with the yelk-bag of a bright red colour contrasting with the pale blue or peach-blossom tint of the body. His specimens measured, when hatched, five-eighths of an inch in length. When the yelk-bag has been absorbed the perpendicular lateral bars on the sides of the body make their appearance, and the fins have become thoroughly formed.

The fry of the Salmon, an inch long, have the head and eyes large, and the body of a pale-brown colour, with dusky grey bands across the sides. A portion of the ovum still hangs below the abdomen. The young Salmon of the first year has been called a pink; in the second year, until it goes down to the sea, it is a smolt; in the autumn of the second year it is a salmon peal or grilse. The young fish live on insects. Yarrell records that pinks from the river Lune were put into a small lake called Lillymere when three inches and a half long. After sixteen months they had become salmon peal fourteen inches long, and weighing fourteen ounces. Nearly a year later the length had increased by two inches, and the weight by nine ounces. Smolts are about six inches and a half long, and have the upper half of the body blue. The fish goes to sea in its migratory dress.

After going down to the sea the fish grow rapidly, and are always much larger than those which have been kept in ponds or lakes. They travel down the river in family shoals of forty, sixty, or more, moving at the rate of about two miles an hour. When the young reach any rapid current they at once turn their heads up the stream, till at last one or two bold ones allow themselves to be carried over the rapid, when the entire flock follow one by one, and keep their heads up-stream till they reach comparatively still water, when the head is once more turned to the sea, and the journey continued. The migration, according to Mr. John Shaw, continues during nearly the whole of a month. The travelling fish were six to seven inches long, and the shoals were largest and most numerous in the second week of the month. They begin to descend the rivers in March, and the descent continues through April, and part of May. They at first keep towards the sides of the river, but as strength is gained take to the mid stream. On meeting the tide the shoals rest for a day or two till accustomed to the brackish water, and then start off suddenly to the sea. Fishes which have been marked, and have gone down in April, or the beginning of May, return by the end of June, weighing from two to three pounds or more, and in July and August the weight varies from two to six pounds. These fish breed in the winter, though the eggs, in a grilse, are about as large as those of a full-grown

Salmon. A much smaller number of eggs, however, is developed. The grilse, on returning from the sea, remain for a long time in brackish water before pushing up to the tributary streams. All the fish do not return to the river from which they started, for some which have been marked have been taken in adjacent rivers. Salmon which go down from the Tweed have been caught on the Forth, and it has been suggested that when the Salmon have wandered far at sea a change in temperature may compel them to enter the nearest estuary which can be found. The Salmon at sea is a voracious feeder. Dr. Knox found in the stomach eggs of Sea Urchins, and other Echinodermata with some Crustacea. Other writers have remarked that their favourite food in the sea is the Sand Eel, with which they are easily taken. Sometimes a fish will have two or three full-sized Herrings in its stomach. They are readily captured in rivers with the common earth-worm, and by the artificial fly. The largest specimen brought to the London market of which there is record was a female weighing eighty-three pounds; and fish have been taken with the rod and line in the Tweed in former years which have weighed seventy pounds, but such weights are very unusual. At sea Salmon are sometimes caught in a net, for they swim near into shore, and ropes are stretched so as to enclose the fish and drag them towards land. Yarrell records that when the fish are seen coming up the river a boat is rowed off quickly from the fisherman's lodge with a net attached to it, which is dropped into the water and taken in a sweep, so that the fish are surrounded. Frequently dogs are trained to assist in fishing, either by driving the fish, as they would drive sheep, or by swimming across the river with lines attached to the net. Some Salmon for the English market are obtained from Norway, and the species frequents nearly all the streams which empty into the North Sea, but is not found in the Mediterranean. It does not occur farther south than the 43rd parallel of latitude, and south of the 55th parallel it becomes scarce. In Germany it occurs in the Rhine and its tributaries, in the Oder, the Vistula, the Weser, and the Elbe. It is less frequent in the west of France and the north of Spain. It is found plentifully in Russia, Scandinavia, Iceland, and Greenland. According to Brehm, the Salmon enters the Rhine in April, and has reached Basle in May. It makes its way through various small streams into several of the Swiss lakes, and reaches a height of more than 4,000 feet above the sea. In the Elbe they go up to the mountains, and reach as far as the Fichtelgebirge. The same species occur in North America.

THE GREY TROUT.*

Under the name Trout are included the Grey Trout, Salmon Trout, the Common Trout, the Great Lake Trout, and the Loch Leven Trout of North Britain. The Grey Trout is easily distinguished by the remarkable squareness of the outline of its operculum, which is relatively larger than in the Salmon; its teeth too are longer and stronger than in Salmon, and the outline of the tail, owing to the growth of the central caudal rays, becomes convex in the older fish. It is found in many British rivers, and Yarrell quotes it from the rivers of South Wales, Cornwall, Dorsetshire, the Cumberland streams which run into the Solway Firth, and it occurs all round the northern shores of Ireland. Dr. Günther regards the Lake Trout of the Orkneys, which does not migrate, as a distinct species. It usually weighs less than fifteen pounds, but sometimes reaches a weight of twenty pounds; the flesh is paler than that of the Salmon, and it is less valued for food. Lord Home mentions that the Bull Trout, as this species is sometimes called, comes up the Tweed first at the end of April or beginning of May, when the fish weigh from two to five pounds. Towards the end of November, however, they come up in thousands, and then weigh from six to twenty pounds. The length of the head to that of the body is as one to four. The lower jaw of the male elongates, though to a less extent than in the Salmon. The dorsal fin commences exactly half way between the extremity of the nose and the origin of the outermost rays of the tail. The scales are rather smaller than those of the Salmon; between the lateral line and dorsal fin there are twenty-six, while below the lateral line there are about twenty-five rows. The anal fin is nearer the tail than in the Salmon. Usually there are fifty-nine vertebrae, or one fewer than in the Salmon. The shoulders are thicker than in the Salmon, and the bases of the fins and fleshy part of the tail are stronger. In the spawning season the head of the male becomes olive-brown, and the body orange-brown, while the females are blackish-grey.

* *Salmo cambricus*.

The SALMON TROUT (*Salmo trutta*) has the gill-cover, or operculum, intermediate in form between that of the Salmon and the Grey Trout. The teeth are more numerous and more slender than in either of these fishes; those on the vomer extend almost throughout its length; the tail is relatively smaller and shorter than in the Salmon. The body is rather deep in proportion to its length; the scales are a longer oval than those of the Salmon; there are twenty-nine above the lateral line and twenty-two below it. Compared with those of the Salmon, the fins are of lighter colour and the body darker. The spots are somewhat cross-shaped and chiefly above the lateral line. The cheeks and gill-covers are silver-white, and the pectoral fin is bluish-white. This species especially abounds in Scotland, and is valued as inferior only to the Salmon. It is caught in Ireland, Wales, the Severn, and the South, West, and North of England. Sir William Jardine mentions that this species enters every river and rivulet along the Scottish coast in immense numbers, feeding on flies, beetles, and other insects, especially the sand-hopper. Two hundred are frequently taken at a single draught of a sweep net. Lord Home states that he never saw one in the Tweed weighing more than seven pounds.

The COMMON TROUT (*Salmo fario*) is found in most of the rivers and lakes of Great Britain. In battle a Trout vanquishes a Pike, and the fish is especially remarkable for caution, vigilance, and valour. The Trout usually spawns in the month of October. The eggs and milt appear to retain their vitality after the fishes are dead, for the ova have been fecundated artificially when the fishes have been dead for three days. The usual number of vertebrae in the Common Trout is fifty-six. The largest caught in the Tweed by Lord Home weighed five pounds, but in the Leet specimens were killed weighing seven pounds. He remarks that the nature of the soil through which the stream flows exercises considerable influence on the colour, size, and quality of the fish. In the rivers Eden and Leet the bodies are marked with bright red spots, fins and sides orange-coloured, the flesh a deeper red than that of the Salmon, and is almost as full flavoured. The food of these fish consists of small molluscs, caddis-flies, and other flies abounding where the banks of rivers are calcareous. They feed towards evening. The spots and colours are generally most brilliant where the bottom is gravelly. The fish is finest in flavour from the end of May to the end of September. In the second year the Trout are said to associate with the Minnows, and in the third year, when they appear in the shallows, are about seven or eight inches long. When well fed, they increase from one to ten pounds in four years. A Trout was taken from a branch of the Avon at Salisbury which weighed twenty-five pounds. Trout have often been kept alive for long periods in wells, and at Broughton-in-Furness one is recorded to have lived in a well for fifty-three years. It occurs in several of the Irish loughs, where the bottom is more or less rocky, and it is said to have been caught in Lough Neagh forty inches long, and weighing thirty pounds. This species presents two well-marked varieties, one found in Scandinavia, Iceland, and Scotland, and the other in England, France, Central Europe, Russia, and the Maritime Alps.

The GREAT LAKE TROUT (*Salmo ferox*) is found in most of the larger and deeper lochs of Scotland and Ireland. It seldom ventures up or down streams, and never descends to the sea. It feeds almost entirely on smaller fishes, and is generally taken on trolling lines baited with a small Trout. The flavour is coarse, and the flesh has an orange-yellow colour. Fine specimens from Ulleswater are said to weigh between fifty and sixty pounds. When full grown and in season it is purplish-brown above, changing through reddish-grey into orange-yellow on the breast and belly. When newly caught, the fish appears as though glazed over with a tint of lake colour, which disappears as it dies. The gill-covers are marked with large dark spots, and the body is covered with markings; the fins and lower part of the body have a rich yellowish-green colour, which becomes darker towards the ends; the tail is more than usually broad and powerful. The scales are more circular than those of the migratory species of Trout. This species is met with in the great lakes of Scandinavia. There is one ray less in the dorsal fin than in that of the Common Trout.

The most southern Trout of the whole world is the *Salmo macrostigma*, from Algeria, which reaches a length of six or seven inches. It is covered with 122 transverse series of scales. Trout occur in Spain, but the species have not been accurately determined. There are two or three species in the rivers of Dalmatia. The Great Dalmatian Trout (*Salmo dentex*) reaches a length of forty-four inches. The *Salmo obtusirostris*, rarely more than a foot long, is also found in the Tiber. The Lake of Garda contains the *Salmo carpio*; the Lake of Geneva the *Salmo lemanus*, and this species is also



COMMON TROUT.

found in the Lago Maggiore. It has a green back and silvery sides and belly, with small cross-shaped black spots on the sides. The *Salmo rappii* and *Salmo lacustris* are both found in Lake Constance, the latter ranging into the lakes of Upper Austria. The former is rather the larger species, but both reach a length from two feet six to three feet. The *Salmo marsilii* of the mountain lakes of Upper Austria is remarkable for having from ninety to a hundred pyloric appendages to the stomach, about twice as many as are usually found in Trout. This species reaches a length of three feet. *Salmo microlepis* is found only in the rivers of Hungary. In France, the rivers running into the Atlantic yield the *Salmo argenteus*, which reaches a length of two feet and a half. There are several Trout peculiar to Scandinavia and Finland, others are found in the Crimea, in Armenia, the rivers of Hindu Koosh, and the Pacific coast of Northern Asia and North America, especially British Columbia, while to the east of the Rocky Mountains other species, which do not migrate, are found in the great lakes.

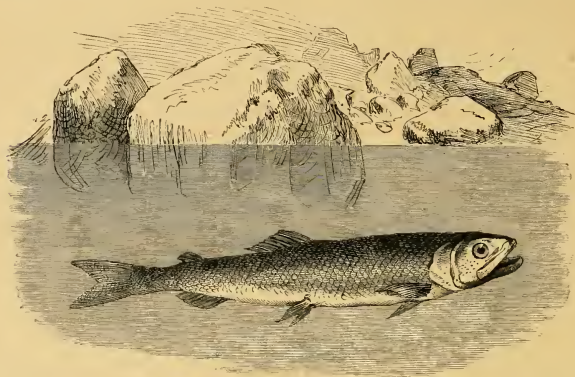
The CHARR (*Salmo alpinus*) is remarkable for the smallness of its scales. In the breeding season the belly acquires a bright red or orange tint, and they are hence called Rothföhren by the Swedes. They are found throughout the lakes of Switzerland, Germany, the British Isles, and Scandinavia. In form they vary with the locality. Mr. Thompson states that in some lakes they are nearly as round as an Eel, while in others they approximate to the form of a Herring. In Windermere they generally weigh from half a pound to a pound or more. Formerly the Charr occurred in Lake Llanberis, but the waters from a copper mine drove it down to the sea, where it still continued to be caught at the mouths of rivers on the coast. The Charr generally live in the deepest parts of the lakes. The stomach is commonly empty, though it sometimes contains small fresh-water Crustacea. The spawning season is in November and December, when the fish make their way into the stream which runs into the lake, though the spawn may be deposited in the lake itself where the bottom happens to be stony. This species is in the greatest perfection for food between July and October. The Charrs have been separated from the Salmon as a sub-generic group called *Salvelini*, characterised by having teeth only on the head of the vomerine bone, while all the true Salmon have teeth not only on the head of the bone, but along its length. Most of the Charrs have teeth in the median line of the hyoid bone. They are a large group, comprising about thirty species.

Among the European species are the Ombre Chevalier (*Salmo umbla*), which is limited to the Lakes of Constance, Neuchâtel, and Geneva; the *Salmo salvelinus*, which is not clearly distinguished from *Salmo umbla*. It is characteristic of the alpine lakes of Bavaria and Austria, but also occurs in Sweden. *Salmo nivalis* is a Charr from the lakes and rivers of Iceland, which reaches a length of twenty-one inches. The Windermere Charr (*Salmo willughbi*) is also found in some of the lochs of Scotland; *Salmo killinensis* is known only from Inverness-shire, and grows to a length of ten to fifteen inches. *Salmo perisii* is found in the lakes of North Wales. *Salmo grayi* is the Fresh-water Herring from Lough Melvin, in Ireland. Another Irish species, seven or eight inches long, has been named *Salmo colii*. The Salmon of the Danube, which when old attains a reddish tinge, is named *Salmo hucho*, and is characterised by wanting the median teeth on the hyoid bone. Another species, *Salmo lossos*, frequents the rivers flowing into the Baltic, and has been found in the river Kama, as well as in the Caspian Sea. There are several Asiatic species of this group, such as the *Salmo fluviatilis*, which does not appear to be migratory, and sometimes reaches a weight of eighty pounds in the Siberian rivers. *Salmo erythrinus* is a Charr from the mountain lake Frelicha, which communicates with the north-east of Lake Baikal; and there are other species in the rivers which make their way into the Pacific. Two species of Charr are recorded from the fresh waters of the Pacific side of North America, and several others from the lakes and rivers of the eastern side of that continent. *Salmo hudsonicus* is found in Hudson's Bay, Labrador, and Newfoundland. Other species have been found in the highest northern latitudes.

The genus *Oncorhynchus* includes several species of migratory fishes, with an elongated anal fin, having more rays than the Salmon found in the American and Asiatic rivers which flow into the Pacific. The Californian Salmon belongs to this genus. The *Oncorhynchus sanguinolentus*, which often weighs from ten to twelve pounds, acquires a blood-red colour on the sides in October, but the colour fades to a brick-red tint in January. Its eggs are large.

The next important genus in this family is *Osmerus*, of which there are three well-known species: *Osmerus thaleichthys*, common in the Bay of San Francisco, can be burned like a candle;

Osmerus viridescens, occurring on the Atlantic coast of the United States; and the SMELT (*Osmerus eperlanus*), which is common on the coasts and in the fresh waters of Northern and Central Europe. It is plentifully taken on the rivers of the east coast of England and Scotland, and is termed Smelt by the Danes. It is found in fresh water only from August to May. After depositing its small yellow eggs it returns to the sea. The eggs, unlike those of the Salmon, are not covered over. The Smelt is remarkable for its cucumber-like odour, which becomes less powerful when the fish has been some time out of water. It is one of the most delicate and exquisitely flavoured fish brought to table. Yarrell mentions that they have been kept for several years in ponds having no communication with the sea, and had in no way deteriorated in size or flavour. Occasionally specimens have been caught thirteen inches long, but the usual size is about seven inches. The back is of a transparent greenish tinge, and the sides are silvery. The scales are small, oval, and deciduous. The lower jaw is longer than the upper jaw.



SMELT.

The largest teeth are on the vomer and fore part of the tongue: there is a double series of teeth on the mandible. There are usually about sixty vertebrae and very few pyloric appendages to the stomach.

The CAPELIN (*Mallotus villosus*) is one of the smallest of the Salmonidae, found on the shores of Kantschatka and Arctic North America. It lives on the sea-bottom, and comes to the surface to spawn, when it often congregates in incredible numbers. It is eaten fresh in Iceland, and dried in Greenland. It furnishes one of the most important baits for the Newfoundland fisheries.

Coregonus is a genus of fishes found in the fresh waters of the north temperate regions of the Northern hemisphere, but many species periodically move into the Arctic Ocean. Dr. Günther states that they are less variable than the Trout, and all the species are characterised by having the body covered with medium-sized scales, by a deeply forked caudal fin, a large air-bladder, and a horseshoe-shaped stomach, to which there are numerous pyloric appendages. The *Coregonus oxyrhynchus*, well known on the coast and in the fresh waters of Holland, Germany, Denmark, and Sweden, has the snout produced in the upper jaw into a fleshy conical process. The snout is also somewhat prolonged in the Swedish species *Coregonus lloydii*, where, however, it is much thicker.

Coregonus quadrilateralis has the profile of the snout remarkably rounded, and has the eye very large. It reaches a length of eighteen inches, and is characteristic of the northern parts of North America. Several species have the snout obliquely truncated; among these are the *Coregonus lapponicus*, from Lapland, and the *Coregonus lavaretus*, which is found in the great lakes of

Switzerland, the Tyrol, Prussia, and Sweden. Fine specimens reach a length of two feet. There are several other species found in the lakes of Central Europe and Sweden, but all have the same truncation of the snout; other species are confined to the Siberian rivers; several are found only in Lake Superior and other lakes of Northern and Arctic America.

Another group of species has the snout vertically truncated, and of these the *Coregonus clupeoides* is known only from the lakes of Great Britain. It grows occasionally to a length of sixteen inches, and feeds on minute fresh-water crustacea, larvæ of insects, water-beetles, and small red worms. In Loch Lomond, where they are plentiful, and caught with the drag net, they are known as Fresh-water Herrings, or Powans. They are greatly valued for food, and are in the best condition in August and September. The *Coregonus albula*, which is found in the north of Europe, has the lower jaw longer than the skull. Another British species, found in Dumfriesshire, is known as the Vendace (*Coregonus vandesius*). It has the dorsal and ventral fins long, and the tail deeply forked. These fish swim in great shoals, and retire into deep water in warm weather. They congregate in great numbers at spawning time, which is about the beginning of November. They resemble the Smelt in flavour. The females are about eight inches long, while the males are about an inch shorter. The colour of the back is brown, and the sides are tinged with yellow.

The POLLAN (*Coregonus pollan*) is an Irish species of this genus, remarkable for the shortness of the head and depth of the body. It has the aspect of a fresh-water Herring, and, like the Herring, is gregarious. It reaches a length of ten or eleven inches. *Coregonus lucidus*, from Great Bear Lake, is known as the Herring Salmon; *Coregonus clupeiformis*, found in Lakes Erie and Ontario, is locally known as the Fresh-water Herring, and sometimes as the Shad Salmon.

The GRAYLING (*Thymallus vulgaris*) is found in the fresh waters of Central and Northern Europe, and is well known in various parts of England and Wales. Large specimens may weigh from four to



GRAYLING.

five pounds. It is in the best condition in October and November, flourishes best in rivers with a rocky or clear bottom, and is unable to exist for long in muddy ponds. It feeds on various flies, which are imitated by anglers, and eats the smaller fresh-water mollusca, such as Neritine and Physæ. When freshly taken from the water it has an odour like thyme. It reaches a length of ten inches. It is marked on the sides with dusty longitudinal bars; the general colour is a yellowish-brown, but the scales reflect many colours in different lights. Towards spawning time the pectoral fins become

reddish. The dorsal fin is elevated with more rays than in the species of *Coregonus*, the fish is of a violet colour, with purple spots, and the trunk is marked with a few small round black dots.

The *Argentina hebridica* is a member of another genus, which, while entering fresh waters, is also found in the European seas at great depths. It somewhat resembles a Smelt in form, size, and odour, but is covered with rather large scales. Species of this genus have been dredged from a depth of over 2,000 fathoms in Arctic and Antarctic waters.

FAMILY VIII.—PERCOPSIDÆ.

The Percopsidæ, represented by *Percopsis guttatus*, are characterised by having the body covered with ctenoid scales. The species is found in Lake Superior.

FAMILY IX.—GALAXIDÆ.

The Galaxidæ include two genera of fresh-water fishes, which all have the body naked, and have hook-like teeth on the tongue, and conical teeth in the jaws and on the palatine bone. The species occur in Australia, New Zealand, and the southern part of South America. They vary from two inches to about seven or eight inches in length. The genus *Galaxias* has only been found burrowing in clay, at some distance from water.

FAMILY X.—MORMYRIDÆ.

This family comprises three genera of fishes from tropical Africa. The pre-maxillary bones unite into a single bone; the inter-operculum is sometimes rudimentary. All the fins are well developed, but there is no adipose fin. A series of pores extends along the base of the dorsal and anal fins. The genera are distinguished by the presence or absence of teeth on the tongue, and the species are defined by the form of the dorsal fin, length of the snout, and the size of the scales. Most of the species of *Mormyrus* are found in the Nile, where the other genera, *Mormyrops* and *Hyperopisus*, also occur.

FAMILY XI.—GYMNARCHIDÆ.

The *Gymnarchidæ* are known only from the *Gymnarchus niloticus*, found in the Nile and rivers of West Africa. It reaches a length of six feet, has an eel-like body, and is chiefly remarkable for the cellular character of the air-bladder, which is capable of being distended. As in the preceding family, the upper jaw is formed of both the maxillary and pre-maxillary bones, and there is similarly a cavity extending into the interior of the skull on each side of the parietal bone, but covered with a thin bony plate. Another point of resemblance is a series of pores along the base of the dorsal fin. In this fish, however, the anal and ventral fins are absent. The tail tapers, and has no caudal fin. It resembles *Mormyrus* in having an imperfectly developed electric organ on the tail, with the usual prismatic structure, but without electric functions.

FAMILY XII.—ESOCIDÆ.

This family comprises the Pikes, which all belong to the genus *Esox*, and occur in the fresh waters of the temperate parts of the northern hemisphere. Several species of this genus are limited to North America; but the European Pike (*Esox lucius*) also occurs in the northern parts of North America, as well as in Northern Asia.

THE PIKE.*

The Pike (*see figure on p. 1*), when full grown, may reach a length of five or six feet. In Loch Lomond, examples have occasionally been taken weighing about eighty pounds; one is recorded from the Shannon that weighed ninety-two pounds. The fish is certainly long-lived, and Gesner refers to an example, said to have been nineteen feet long, which weighed 350 pounds. In the Middle Ages rings were sometimes put in the gill-covers of fishes; and on evidence of this kind it has been supposed that Pike have sometimes lived for more than 250 years. The young are said in the first year to grow to a length of eight or ten inches; in the second year they increase to twelve or fourteen inches; and in the third year the length is eighteen or twenty inches; after which the weight and size augment in proportion to the supply of food, for the Pike digests rapidly, and therefore, stimulated by hunger, is bold and active in the pursuit of prey. The stories of its voracity are almost inexhaustible. In one case a Pike swallowed the head of a swan; in another case this fish seized on the lips of a mule that had gone down to the Rhone to drink. It is said sometimes to fight with the otter for possession of fish. The instances are many of Pike seizing the hands and feet of bathers. An early writer, Dr. Crull, quoted by Couch, states that a Pike had been captured

* *Esox lucius*.

with an infant child in its stomach. Ducks, geese, and water hens are all sometimes found in the stomachs of these fish. Instances have been known of a Pike swallowing one of its own species scarcely smaller than itself, but then the devoured fish can only be taken into the body of the devourer gradually, as digestion progresses. The more ordinary food of the Pike, however, is furnished by frogs and small fishes. According to Mr. Jesse, eight Pike, of about five pounds' weight each, consumed 800 Gudgeons in three weeks. They readily take Roach and Carp, Tench, and probably most fresh-water fishes, though they are believed to avoid Perch and Sticklebacks.

The Pike is supposed to first spawn when it is three years old. The spawning season lasts for about three months, but the ova are usually deposited in March. A single Pike, weighing thirty-five pounds, may contain more than 270,000 eggs. The young are hatched in about a month, but comparatively few reach maturity. The Pike is well known to travel over land, and annual migrations of the fish have been recorded. They come in the spring in great shoals out of the Isle of Ely into the river Cam. In the earlier times of history, the Pike appears to have been rare in England, though the occurrence of its bones in the peat of the fens may be taken as evidence that it is a native fish and has not been artificially introduced. In former times Pike were held in greater favour as food than now, and they were fattened by being kept in cages in the river Cam, often selling for large prices. The Pike is said to be at its best when it has preyed upon the Smelt. In Lapland, it is dried for winter use. The old families of Lucie, of Cockermonth, and Egremont, have on their arms three silver pikes on a red field. The Pike has a long and somewhat compressed body, with a rounded back, the snout is depressed, broad and long, but not so long as the lower jaw. The body is covered with small cycloid scales; the lateral line is not well marked. There are no barbels; the dorsal fin is placed far back on the tail, and is opposite to the anal fin. The caudal fin is broad and forked. The teeth in the mandible form a single series, and vary in size. Teeth also occur in bands on the pre-maxillary bones, vomer, palatine bones, and hyoid, but there are no teeth on the maxillary bones. There are no scales on the sub-operculum and lower part of the opercular bone. The pseudo-branchia, or gills on the operculum supplied with arterial blood which is afterwards conveyed to the eye, have a glandular character, and are covered by the mucus membrane which lines the gill cavity. There are no pyloric appendages to the stomach; the air-bladder is simple. The colour of the head and back is olive-brown, the sides become paler, and the belly is silvery white; the body is mottled over with more or less round spots, which sometimes form cross-bars on the tail. The dorsal, anal, and caudal fins are generally spotted with brown. The Pike often sleeps or remains in an unconscious state, in quiet parts of rivers; when thus dozing it may be taken with a kind of noose.

FAMILY XIII.—UMBRIDÆ.

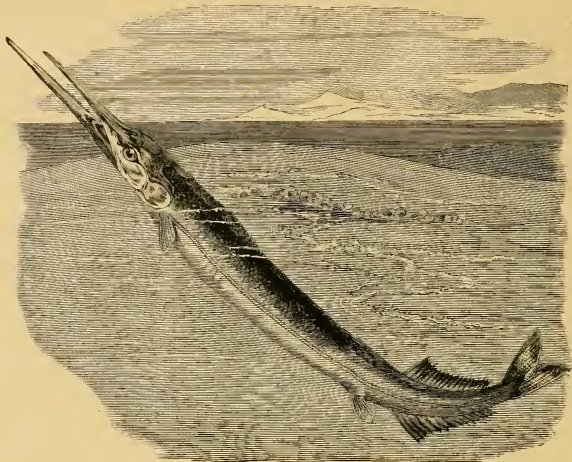
The Umbridæ are known only from the genus *Umbra*. *Umbra krameri* is a small fish three or four inches long, which is found in stagnant water in Austria and Hungary, and has occurred in the neighbourhood of Odessa. The *Umbra limi* from the fresh waters of the United States is rather smaller. The dorsal fin in these fishes is rather long, the ventral fins are below its commencement, and the small anal fin is below its termination. The caudal fin is rounded. The head is broad and blunt, with short jaws armed with small slender teeth.

FAMILY XIV.—SCOMBRESOCIDÆ.

This family comprises genera which are characterised by having a series of keeled scales along each side of the belly. The dorsal fin is opposite the anal fin, and both are placed in the caudal region of the body. The lower pharyngeal bones are united together. The intestine is quite straight, without a distinct stomach. The air-bladder, which is large, is sometimes cellular, but has no pneumatic duct; it is occasionally absent.

The genus *Belone* is well known, from a multitude of species which chiefly frequent tropical waters, but are widely distributed. Many species are found in the West Indies and adjacent coasts of Brazil, and one (*Belone tenuata*), which has the rays of the dorsal fin all of about the same length, is found in the river Capin, in Brazil. Other forms, like *Belone euxini*, are limited to the Black Sea; several, such as *Belone acus*, are found only in the Mediterranean. One species frequents the coast of Portugal, and the Common Garfish (*Belone*

vulgaris) ranges round the Northern shores of Europe. The species extend down both the Atlantic coast of Africa and the Red Sea, abound in the Indian and Chinese Seas and Indian Archipelago, reaching to Australia on the one hand, and by way of the Sandwich Islands to the Californian coast, on the other. This genus is characterised by a slender, elongated body, which has the jaws prolonged into a slender beak; but in the young the jaws are short, and the premaxillary bones, like the lower jaw, become lengthened as the fish reaches maturity. Both jaws are armed with bands of minute teeth, and larger conical teeth, which are widely separated, though certain species have no teeth on the palate. Among such may be mentioned the *Belone cancelloides*, from the rivers of Borneo.



GARFISH.

The Garfish (*Belone vulgaris*) is often taken with the Mackerel, in advance of which it usually swims. It is plentiful all along the English Channel in spring, and occurs on most parts of the British coasts. The majority of the fish retire in the winter into deep water. The species is extremely active, swims near to the surface, and takes the bait readily. Couch records that it often feeds on a black fly, which alights on the sea in fine weather, the stomach being sometimes filled with it. It also feeds on the Herring, but the stomach is only large enough to hold one at a time. It is largely used for bait. When newly-caught it has a disagreeable odour; the flesh has much the flavour of Mackerel, but is drier. Full-grown specimens vary from two feet to two feet six inches in length, but the body is only one inch and a half deep. The head and back are of a dark bluish-green tint, becoming paler at the sides, and brilliant white on the belly. The ventral fin is about midway between the operculum and the tail; the dorsal and anal fins are similar to each other, and near to the caudal fin. The caudal fin is forked. The body is covered with small scales, which are very thin. The upper jaw, as in many birds, has a jointed union with the skull. The bones of the Garfish are green.

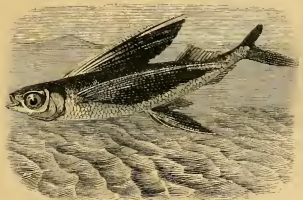
The genus *Scombresox* has a close general resemblance in form of body to *Belone*, the jaws being similarly elongated, and the body similarly slender, and covered with thin deciduous scales. The essential difference between the genera consists in the development in *Scombresox* of a number of detached finlets posterior to the dorsal and anal fins, which extend to the caudal fin. In this genus, too, the lower jaw is longer than the upper. Several species are known from New Zealand, Japan, Chili, the Mediterranean, and both sides of the Atlantic. The last species referred to—*Scombresox saurus*—commonly known as the Saury, or Skipper, is usually from a foot to eighteen inches long, and the depth of the body may be about an inch. The teeth are small; the upper jaw has a hinge movement, as in *Belone*. The food of this fish consists chiefly of the smaller crustacea, though the stomach occasionally contains seaweeds. Like the allied *Belone*, it resembles the Mackerel in flavour, and swims on the surface. It travels in shoals, and has the power, when followed by the Porpoise, or carnivorous fishes, of springing out of the water to a height of several feet, and passing over a distance of thirty or forty feet before it again touches the sea. Couch, indeed, mentions that, when pursued, the fish rush along the surface, like pebbles making "ducks and drakes," for more than a hundred feet, apparently by the repeated touch on the water of the pectoral, ventral, and other fins and finlets on the lower part of the body. Several thousands have sometimes been taken in a single cast of the seine net.

The third genus—*Hemirhamphus*—includes about forty species, mostly from tropical seas, though they are perhaps more abundant in the East Indian Archipelago, and adjacent waters, than elsewhere, and certain species, like *Hemirhamphus fluviatilis*, occur only in the rivers of Java and other Eastern countries. *Hemirhamphus* is remarkable for having the lower jaw prolonged into a slender, compressed beak, while the upper jaw is short. Both jaws are armed with minute teeth, which in some species are tricuspid. The body in these fishes is elongated and slender, and covered with scales, which are never small. It is worthy of notice that the lower jaw is short in young specimens. The young of *Belone* have been mistaken for *Hemirhamphus*, even by Yarrell and Couch. The species are mostly small, and range from a length of two inches to a foot. The *Hemirhamphus cuspidatus*, from the Indian Ocean, has the prominent part of the lower jaw remarkably short, and the pectoral fin about a quarter of the total length of the animal.

Arrhamphus sclerolepis, from the coast of Queensland, is the only species of its genus, and differs from *Hemirhamphus* in the shortness of the lower jaw. The scales are keeled.

FLYING FISH OF THE GENUS EXOCOETUS.

This genus includes a large number of species, which all have the pectoral fins very long, and capable of being used to support the fish when moving through the air. In some species the length is more than half that of the body; in other species it is somewhat less. These fishes, which abound in the seas between the Tropics, and frequent the open ocean, are widely distributed, and often extend north and south into temperate waters. Many species are very small, and do not exceed a length of two to three inches, and none are large, though the *Exocoetus lineatus*, from Madeira, and some other species reach a length of sixteen inches. Certain types have barbels below the mandible. The jaws in these fishes are short, and the teeth are minute, or may be wanting altogether. The oblong body is covered with large scales. The best-known of the Flying Fishes is the *Exocoetus*



EXOCOETUS VOLITANS.

evolans, which ranges from Australia and the China Seas over the Indian Ocean, and is met with in the West Indies, Mediterranean, and sometimes on the coast of England, shoals having been seen off Portland and in many other localities. The snout is blunt, something like that of the Grey Mullet; the body is wide across the back, compressed at the sides,

and becomes smaller towards the tail. The pectoral fins extend backward as far as the root of the caudal fin, and the ventral fin is placed in advance of the dorsal fin, which is on the hinder part of the body. The pectoral fins are black, with the lower border whitish, and the ventral fins are white. The caudal fin is unevenly forked. The usual length of this species is about sixteen inches, though Couch refers to an example which was twenty inches long. The body is dark on the back, has a bluish tinge on the sides, and is white below. The longest time for which these fish have been seen to sustain themselves out of the water is thirty seconds. There is no visible movement of the pectoral fins during this time, and it is probable that the impetus is given to the fish by its tail while still in the water. The longest flight observed has exceeded two hundred yards. The usual height of the fish above the surface of the water when thus flying is from two to three feet; but they have been known to come on to ships of war at a height of more than twenty feet above the sea. They are stated never to raise themselves above the height which they first reach. Thousands often rise out of the sea at once, and move in many directions. When kept in vessels of sea-water they can rise out of it to a height of only a few inches. In all these fishes the air-bladder is large, and Humboldt mentions that in a fish sixteen centimetres long the air-bladder has a length of nine and a breadth of two and a half centimetres. The stomach has been found to contain small fishes, crustacea, and many small marine animals. The *Exocoetus volitans* is limited to the Mediterranean. This species belongs to the group with long ventral fins. The Flying Fish have many enemies. Prominent among these are the Bonito, Tunny, Porpoises, and sea birds; and they are good eating.

FAMILY XV.—CYPRINODONTIDÆ.

This family comprises an assemblage of about twenty genera of small fishes, which are mostly viviparous, and found in the fresh waters of Southern Europe, Africa, Asia, and America. The family is subdivided into two principal groups. The first of these, called Cyprinodontidæ carnivoræ, has the bones of each mandible firmly united, and the intestine short, or but slightly convoluted. In the second group, Cyprinodontidæ limnophagæ, the dentary bone is movable upon the other bones of the mandible; the intestine has many convolutions, and, as with some of the genera of the other group, the sexes present distinct external characters. Cyprinodon has several species, confined to the fresh and brackish waters of the Mediterranean region. Cyprinodon calaritanus occurs in the South of Europe, and in the hot springs of the Sahara. The males are of an olive colour, with nine or ten narrow silvery crossbars, but the females are silvery on the sides, with black vertical stripes which do not extend on to either the back or the belly. Cyprinodon dispar is found in Abyssinia, and also in the Dead Sea. Cyprinodon cypris is from the river Jordan and Bagdad. The New World species are from Long Island, Texas, and other parts of the United States. The species range from an inch to a length of about five inches. The genus Fitzroyia has tricuspid teeth like those of Cyprinodon, but instead of being arranged in a single series, as in that genus, they form several series. The species *F. multidentata* is from Monte Video. The single species of Characodon, from Central America, has the small teeth bicuspid. The Tellia apoda, from the higher pools of the Atlas Mountains, differs from Cyprinodon chiefly in wanting the ventral fins. Haplochilus has slender, viliform teeth in both jaws. The species belong to the Indian region, to tropical Africa, and temperate and tropical America. The genus Fundulus, like the preceding genus, has the upper jaw movable, and capable of being protracted. The species are all small and insectivorous. Fundulus hispanicus lives in the fresh waters of Spain. The known species of the genus Orestias, in which the ventral fins are absent, are all from Lake Titicaca. In Jenynsia the teeth are notched, and the anal fin of the adult male is modified into a conical remarkable organ, in which scarcely any of the rays remain distinct, a character found in several allied genera. Anableps has the arches above the eyes greatly elevated, and the eye itself is divided by a dark-coloured transverse band into upper and lower portions. This is not merely an external character, but the pupil itself is completely divided into two, by lobes of the iris which project from the front and back margins of the eye. The anal fin of this fish is modified in the male into a thick and long conical organ covered with scales, and is perforated at

the extremity. The species of *Anableps* are from the fresh waters of Central America and the Guianas. The second group of this family includes four or five genera of mud-eating fishes. The species are all from the West Indian Islands and Central and South America. The more important genera are *Poecilia*, in which the minute teeth are arranged in bands, and *Girardinus*, in which the pointed teeth are arranged in a single series, and the origin of the anal fin is in advance of that of the dorsal fin. All these fishes are small.

FAMILY XVI.—HETEROPYGIL.

This family is formed for two genera of North American fishes, which have the heads naked and the body covered with minute scales. The dorsal fin is opposite the caudal fin, and both are placed on the caudal region of the body. *Amblyopsis speleus* is a viviparous fish found in the caves of Kentucky, which has the eyes absent or rudimentary, the lower jaw rather larger than the upper, a band of teeth on each palatine bone, and the head covered with vertical wrinkles, which constitute an acute organ of touch. The sense of hearing is also well developed. It is colourless, and has the ventral fins rudimentary, and sometimes entirely absent. It reaches a length of five inches. It is found in the Mammoth Cave of Kentucky. *Chologaster cornutus* is a similar fish, found in ditches in the rice-fields of South Carolina, but differs from the foregoing in possessing eyes. The specific name is derived from the circumstance that the snout is provided with two horn-like processes.

FAMILY XVII.—CYPRINIDÆ.

This vast family comprises more than a hundred genera of fresh-water fishes, and includes the majority of the species from the fresh waters of Europe and Asia, and is well represented in Africa and North America. In Great Britain the group is known from such familiar examples as the Carp, Barbel, Tench, Gudgeon, Gold-fish, Bream, Chub, Roach, Dace, and Minnow. In this group the head is naked, and the body generally covered with scales. As a rule the belly is rounded, the mouth is toothless, and the upper jaw is formed by the pre-maxillary bones. The lower pharyngeal bones are furnished with teeth, which may be arranged in one, two, or three rows. The stomach has no pyloric appendages. The air-bladder is usually large, though its modifications furnish characters for three primary divisions of the family. Dr. Günther regards the Cyprinidæ as including fourteen groups. In the first twelve of these the air-bladder is divided transversely into anterior and posterior portions; and there are never more than four barbels.

In the second division, which comprises the Homalopterina, the air-bladder is wanting. In the third division the air-bladder is more or less completely enclosed in a bony sheath. This group is known from its typical genus as the Cobitidina; the barbels vary from six to twelve.

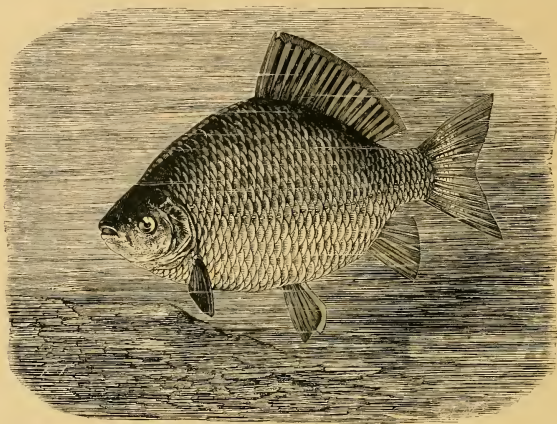
In the first of these three divisions the characters of the several groups are derived chiefly from the characters of the pharyngeal teeth, the modifications of the anal fin, position of the lateral line, and, in some cases, the dorsal fin also furnishes distinctive characters.

The first group, Catostomina, has the pharyngeal teeth numerous, close set, and arranged in a single series. There are no barbels. The dorsal fin is long, and the anal fin short.

In the type genus *Catostomus* the skeleton is remarkable, from the circumstance that many of the bones are so slightly ossified as to consist merely of a delicate bony network. This genus, like nearly all the other members of the group, is confined to North America, and comprises fishes of moderate size. Some of the species have the air-bladder with three divisions, as in *Catostomus carpio*, of the Canadian lakes.

The second group is termed Cyprinina. It has the pharyngeal teeth differently arranged in its representatives in the Old and New World. In the former, the teeth are placed in triple series; in the latter region of the globe the teeth may be in double, or even in single, series. The anal fin is very short, and includes five or six, or even seven, branched rays. The dorsal fin is opposite to the ventrals, and the lateral line runs along the middle of the tail. The scales are cycloid. This is the largest group of the family, and includes many familiar river fishes. The type genus is *Cyprinus*, which has a rounded blunt snout and narrow mouth, with four barbels; the dorsal fin has a strong serrated bony ray. The Carps are fishes of the temperate parts of Europe and Asia, the best known, *Cyprinus carpio*, presents a multitude of varieties in form, characters of skin and scales, and other features. It occurs not only throughout the northern part of Europe, but, according to Dr. Günther, in China, Japan,

Formosa, and Java. It does well in brackish water, and attains a large size in the Caspian Sea. The Carp is long-lived, and is believed to live to a hundred, or even to two hundred years. In Germany the Carp is regarded with a degree of epicurean appreciation which, in Britain, finds no parallel. In both Austria and Prussia they are as much an article of culture as any produce of the land. Carp ponds are somewhat costly to make, for there need to be separate ponds for spawning, for a nursery, and for the ordinary mature life of the fish; and it is stated that the sale of Carp makes no small part of the revenue of the larger landed proprietors in Northern Germany. A fish supposed to be sixty years old had a length of five feet. Other large Carp are referred to as weighing thirty-eight pounds and more. The Carp is tenacious of life, and in winter is kept alive in Holland for weeks, by being placed in wet moss which is hung in a net. The fish at first require to be frequently dipped in water, but gradually adapt themselves to the new condition, and feed on



CRUCIAN CARP.

bread and milk. The ordinary food of Carp consists of larvæ of insects, worms, and various water-plants. It has been known to feed on minnows. It becomes tame in the ponds, and readily assembles to take bread or boiled potatoes. In winter it hides in the mud, and passes months without eating. It breeds usually in the third year, but the number of eggs increase with age, and, in a fish of ten pounds' weight, the eggs number seven hundred thousand. The ova are deposited upon water-plants in May and June, and at this time the female is commonly followed by more than one male. They develop much better in ponds and lakes than in rivers. A remarkable account is quoted by Couch from the *Gentleman's Magazine* of a custom of removing the roe from the living fish, when they are said to acquire a flavour as much superior to that of ordinary Carp as the flesh of the ox is to that of bull, or a capon to a cock. Carp appear to have been introduced into England in the fifteenth century, probably by German monks. The Germans have a prejudice against allowing frogs to enter the Carp-ponds, and Couch, quoting Pennant, states that on fishing a pond in Dorsetshire great numbers of Carp were found, each with a frog mounted on it, the hind legs clinging to the back, and the fore legs fixed in the corner of each eye of the fish, which were thin and wasted. The colour of the body is golden-brown, darker on the head and upper

part of the body, and yellowish-white on the belly. The base of each scale is darker than its other part, and the fins are dark brown. The body is thick; there are two barbels at the upper part of each corner of the mouth, but the lower pair is the larger. The tail is forked. The dorsal and anal fins have a strong ray, which is serrated on the hinder margin.

The genus *Carassius* differs from *Cyprinus* in being without barbels. It is represented by the Crucian Carp — spread through Central and Northern Europe, Italy, and Siberia — and by the *Carassius auratus*, or Goldfish. The Crucian Carp (*Carassius vulgaris*) has the rather feeble stiff ray of the dorsal and anal fins finely serrated. In the Thames it sometimes weighs from one pound and a half to two pounds and a half. It is domesticated on the Continent, and exhibits many varieties. It spawns in June, when the fish assemble together in great numbers. In Siberia it becomes torpid in the winter, and is said to survive in the mud, even when the lakes freeze to the bottom. The scales are large. This species forms a hybrid with the common Carp. Dr. Günther regards the Prussian Carp as a lean variety of the Crucian Carp.

THE GOLD FISH.*

Gold and Silver fish are familiar pets, not only in the ponds of public gardens, but in the humbler aquaria of private houses. They are said first to have been brought to Europe in the seventeenth century, their original home being China, where they are kept in porcelain vessels for the amusement of ladies. The fish is naturalised in Portugal, and a large number of those which reach the London market are brought from Lisbon by trading ships. Blanchard states that in the rivers of France it loses its colour. In the manufacturing districts of England they are often kept in the ponds in which the water from the steam-engine is allowed to run off and cool. Here the average temperature is often about 80° Fahr., and Yarrell records that the fish breed much more readily under such circumstances than when exposed to the variations of climate. The species is apparently capable of enduring even a much higher temperature. Three pairs of fishes put into one of these warm ponds had, in three years, so increased in number that they were then taken out by the wheelbarrow-full. The varieties of colour and size are well exhibited in the collection at Hampton Court. The fins are no less variable than the colour; sometimes the anal fin is double, sometimes there are two, three, or four tails; the dorsal fin varies in length, and occasionally may even be absent; sometimes the eyes are very large and protruding, when the variety is termed the Telescope fish. No specimens are known to exceed a foot in length. A large number of allied genera, with the pharyngeal teeth in three series, occur in the Indian region. Among such are a species of the genus *Catla*, which occurs in the Ganges and Hooghly; *Cirrhina*, *Dangila*, *Osteochilus*, are other genera. The genus *Labeo* has the lips greatly thickened, and each possesses a sort of inner lip covered with a horny sheath which forms a sharp grasping edge, though it is not attached to the bone; the snout is covered with hollow tubercles. The occipital crest of the skull is firmly united to the neural spines of the earlier vertebrae. Some of the species occur in the Nile and other parts of Africa, others belong to the East Indian region. Another group of Carp is characterised by having the greater part of the cheek unprotected by bone. Among these, *Discognathus* presents a singular type in having the lower lip modified into a suction disc, and its pectoral fins are horizontal. The *Discognathus lamta* ranges through all the countries from Syria to Assam, and presents considerable variation in colour, form of the snout, barbels, lips, eyes, and tail. The *Epalzeorhynchus callopterus*, from Sumatra and Borneo, has the snout inflated and bluntly rounded, and furnished with a lateral lobe, which can be freely moved. The *Capeota damascina* is a well-known fish of Palestine, which occurs, not only in the Jordan and Lake of Galilee, but also in the Dead Sea, and has been found in Lake Van, in Asia Minor. The Syrian specimens sometimes reach a length of thirteen inches. The other species of this genus are mostly from Asia Minor.

The genus *Barbus* comprises about two hundred species of fishes, which vary a good deal in their characters. The dorsal fin generally has the third ray enlarged and ossified; it rarely includes more than nine branched rays, and is placed opposite to the root of the ventral fin. The anal fin is short and high. The barbels may be absent, as in some East Indian forms, but the larger number of the fishes have four barbels, though they are sometimes reduced to two. The best known species is the Barbel (*Barbus vulgaris*), a widely-distributed species in Europe, being plentiful in all the rivers which flow into the Black Sea, in the Weser, Elbe, Rhine, Thames, and most northern

* *Carassius auratus*.

waters. It burrows about in the loose soil on the river bottom, and feeds on worms, fresh-water mollusca, water-plants, and small fishes. The eggs are deposited in May or June on stones or water-plants in shallow water. They extend in a string, and may number eight thousand in a full-grown female. They are hatched in from ten days to a fortnight, and reproduce at the fourth year. In cold weather the fish becomes torpid and assembles in great numbers in sheltered places, when it is easily taken with a hand-net. It is even stated that in the Danube ten cart-loads have been taken at one time by divers, who captured the fish in their hands. The usual length is about fifteen inches, though it sometimes reaches three feet. It is stated by Heckel and Kner that the flesh is well flavoured when the fish has been previously kept for some days in pure water. The upper part of the body is greenish-brown, becoming yellower at the sides, and the belly is white. The caudal fins are brownish, and the pectoral, ventral, anal fins, and lips are red. The Barbel appears in the arms of Margaret of Anjou, Queen of Henry VI., foundress of Queen's College, Cambridge. Several species occur in Spain, Italy, Angola, the Jordan, and the Lake of Galilee, and a large number in the Indian Archipelago. A considerable group of species, found in India and Western Africa, is covered with very large scales. *Barbus heteronema*, from Borneo, has the barbels subdivided with long fringes.

The genus *Barbichthys* has the lips thin, with four small barbels; below the eyes the ring of sub-orbital bones is so greatly developed as to entirely cover the cheek. The only species known is from Java, Sumatra, and Borneo. Two genera, also from the Eastern Archipelago, are characterised by having the eyes surrounded with a broad circular fatty eyelid. The genera *Oreinus* and *Schizothorax* have the vent and anal fin enclosed in a sheath, which is covered with enlarged scales; the pharyngeal teeth are in three rows. Both genera are found in the mountain streams of the Himalayas and adjacent regions. *Gymnocephalus dobula* is a Carp with the body naked, but the vent and anal fin are enclosed in a scaly sheath. *Diptychus* has the body only partly covered with scales. It also is Himalayan.

THE GUDGEON.*

The genus *Gobio* is entirely European, and is represented by only two species—*Gobio uranoscopus*, which is confined to Austria, and the Common Gudgeon, which is more characteristic of Western Europe. This well-known fish has two rows of pharyngeal teeth, which are hooked; there may be two teeth in each row, or five in one and three in the other. The barbels are small and placed at the corners of the mouth; the snout is blunt, the profile convex above, the eye behind the middle of the head. In England it is found in most slow rivers that run over gravel, is gregarious, rarely exceeds eight inches in length, and is caught freely with the small red-worm. They are regarded as excellent eating, though, being small, are not much prized. The Gudgeon spawns in May. Yarrell quotes Valenciennes' experiment upon the effect of diminished pressure upon the Gudgeon, in which the fish were placed in a basin under the receiver of an air-pump. The fish could endure to have the pressure reduced to one-half, or even a quarter, without suffering, unless the exhaustion were too rapid, though on being returned to ordinary atmospheric conditions the belly appeared greatly shrunken, and the swim-bladder empty; but in six hours condition was restored, and the swim-bladder again filled with nitrogen gas.

Ceratichthys, *Pimephales*, *Hyborhynchus*, and many other genera are limited to North America. *Cochlognathus ornatus*, from Texas, is remarkable for the jaws being developed into spoon-shaped expansions, one on each side of the upper and lower jaw. These bony masses have their edges sharp and cutting so as to form a beak, which closely resembles that of *Tetrodon*.

The third group in this family is named *Rotheichthyina*. It includes fishes in which the dorsal fin is placed behind the ventral fin. The anal fin is very short, and the abdomen compressed; the mouth has no barbels, and the pharyngeal teeth are in a triple series. The only member of the group is the *Rotheichthys microlepis*, from Borneo and Sumatra.

The fourth group, named *Leptobarbina*, has the lateral line running along the lower half of the tail; the dorsal fin is opposite to the ventral fin. There are four barbels. The only member of this group is the *Leptobarbus hoevenii*, also from Sumatra and Borneo.

The fifth group, named *Rasborina*, also has the lateral line on the lower half of the tail, but the dorsal fin is behind the origin of the ventrals, and the abdomen is not compressed. The fishes are

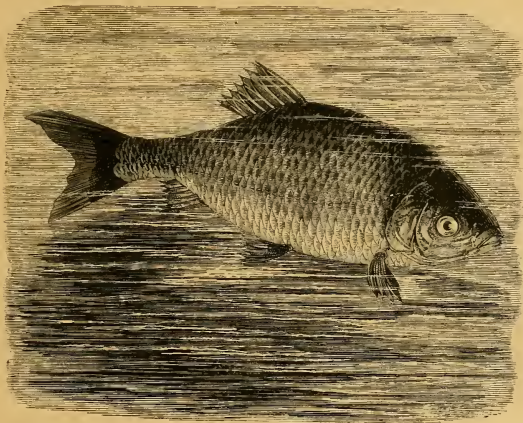
* *Gobio fluviatilis*.

chiefly from India, and the Indian Archipelago. One or two genera like *Aphyocypris*, from China, and *Amblypharyngodon*, have the lateral line incomplete. Some species of the genus *Rasbora* have barbels, though nearly all are without them.

The sixth group, named *Semiplotina*, includes the genera *Cyprinion*, from Syria and Persia, and *Semiplotus*, from Assam. The dorsal fin in these fishes is elongated, with an osseous ray and many-branched rays.

The seventh group, termed *Xenocypridina*, has an osseous ray in the dorsal fin, but the fin is short. Two of the genera are from China, and the third from the west coast of Sumatra.

The eighth group has the dorsal fin short, as in the preceding group, but the osseous ray is absent. It is named *Leuciscina*. The genus *Leuciscus* comprises the greater part of a hundred species, which are widely distributed in both the Old World and America. In this genus the body is



ROACH.

covered with imbricated scales. There are no barbels. The pharyngeal teeth are in a single or double series, and the intestine is short, with a few convolutions. The Roach (*Leuciscus rutilus*) belongs to the Old World section of the genus with the teeth in single series. It is found throughout Europe in all the countries north of the Alps. The body is somewhat elevated, of a silvery aspect, and has three longitudinal rows of scales between the lateral line and the ventral fin. In the full-grown fish the lower fins have a red colour. Its usual length is ten inches, but large specimens may measure as much as fifteen inches. The large scales are easily detached; the lateral line has a downward curve. The mouth is small. The Roach is a gregarious fish, swimming in large schools, and as the reproductive season approaches they make a short migration, leaving the lakes or main streams to ascend the tributaries, and at such times are taken in great numbers. Their eggs furnish food for the Trout. At ordinary times the Roach frequents holes in the beds of rivers. In the Baltic they are said sometimes to be met with in bays near to the land. It is in the best condition for table in October, but is not greatly valued as food. This species forms various hybrids with Breams.

Many species of *Leuciscus* occur in Spain, Portugal, Montenegro, Dalmatia, European Turkey,

the Crimea, and Danube. The *Leuciscus zeregi* is a small fish two inches and a half long, from the Lake of Galilee.

The Chub (*Leuciscus cephalus*) occurs throughout the fresh waters of Europe and Asia Minor. It is common in the Thames, and many of the rivers of England, preferring rapid waters with a clean bed. It seeks shelter in holes equally from the heat of summer and the cold of winter. It, as a rule, takes a mixed diet, made up partly of insects undergoing their metamorphosis in the water, partly of worms and water-plants. It spawns towards the beginning of summer. It does not reach a larger size than a weight of five pounds, and is held in no favour for eating, though Yarrell states it is best when broiled with its scales on. The scales are large and thick; the lateral line is concave in length. The colour is a brownish-green, becoming paler on the sides; the tail and lower fins are reddish.

The Dace (*Leuciscus vulgaris*) has an oblong body, with a moderately broad head and narrow mouth; the middle sub-orbital bones are very narrow. The origin of the dorsal fin is opposite to the hinder part of the root of the ventral fin. The sides have a shining, silvery appearance. There are four longitudinal rows of scales between the ventral fin and the lateral line. The pharyngeal teeth are hooked. It is found in Europe only, and ranges from Lapland southward to the Alps. When fully grown, it is eight or nine inches long, and somewhat resembles the Roach in appearance. It prefers clear streams where the water is deep and the bottom gravelly. Its habit is gregarious; it feeds on worms, and many kinds of soft food. It spawns in early summer. Its flesh is but little valued, though it is preferred to the Roach. Dr. Günther regards the Graining which Yarrell described as *Leuciscus lancastriensis* as a variety of the Dace. Yarrell remarks that the nose is rounder than that of the Dace, the eye larger, the profile of the head straighter, the scales larger, and enumerates various minor differences.

The Ide (*Leuciscus idus*) is a well-known European fish found in the brackish waters of the Baltic, and ranging through the Scandinavian countries, Germany, and Austria. It is also said to have been taken at the mouth of the river Nith, in Scotland. It is a very variable species, with the jaws even in front, and the body slightly elevated. In Sweden, examples have weighed four or five pounds. When boiled in salt water the flesh becomes red, like that of the Salmon. The sides of the fish are typically bluish-grey, but the variety named Orfus is of a uniform orange colour.

The Red-eye, or Rudd (*Leuciscus erythrophthalmus*), is another fish with an elevated body; the part of the belly behind the ventral fins is compressed into a sharp edge, and covered by scales which extend across it. The origin of the dorsal fin is behind the root of the ventral fin. There are three rows of scales between the ventral fin and the lateral line. It is a widely distributed species, occurring in Britain, throughout Europe, and in Asia Minor. Its eyes are bright-red, and the fins are red also, though the colour is more marked in the lower fins than in the upper ones. The body is brown, or sometimes bluish-green. The variety termed the Azurine is remarkable for its blue colour. It is preyed upon by Pike, Trout, and Perch; is good eating, but does not reach a greater weight than two pounds. As in many allied species, the scales become rough at spawning time. There are several hybrids between this species and other allied fishes.

The *Leuciscus muticellus* is a well-known species in the upper parts of the Danube and Rhine, Switzerland, and Italy.

The Minnow (*Leuciscus phoxinus*) is a widely-distributed European fish, ranging from Norway to the Danube, and well known in England. It is the smallest British species of the family. Almost every fish in the river preys upon it. The Minnows have a remarkable habit of arranging themselves in circles, with the snout towards the centre, when any substance which can serve as food is thrown in the water. This arrangement has been compared to the petals of a flower. The Minnow rarely exceeds a length of three inches. The flavour is good, especially when fried, but they can only be taken in sufficient quantity for a meal with a net. They spawn in June on gravelly soil, and are hatched in a few days. The dorsal fin is opposite the space between the ventral and anal fins. The tail is forked, and there is a blackish spot at its base, with many spots extending along the middle of the body, which is otherwise of an olive-brown, becoming lighter at the sides. In summer the belly acquires a pink tint. The pharyngeal teeth are claw-shaped.

More than half the species of *Leuciscus* occur in America, where they are widely distributed in

the United States. Very few have acquired popular names, but among these is the Red-fin, also known as the Red Dace, or Rough-head (*Leuciscus cornutus*), the fins becoming red during the spawning season. It is found in Lakes Erie and Michigan, and other parts of the United States. The Spawn-eater, or Smelt (*Leuciscus hudsonicus*), is a silvery fish with a black spot on the root of the tail, and with a very large eye. It is about three inches long, and occurs in Lake Superior. Many of the American species have the eye large.

The Tench (*Tinca vulgaris*) is the only species of its genus. It has small scales, which are deeply embedded in a thick skin covered with thick mucus. The dorsal fin is short, and has no spine. It is opposite to the ventral fin. There is a short barbel at the angle of the mouth. The pharyngeal teeth are in a single row, are cuneiform, and slightly hooked. It occurs in France, Germany, and



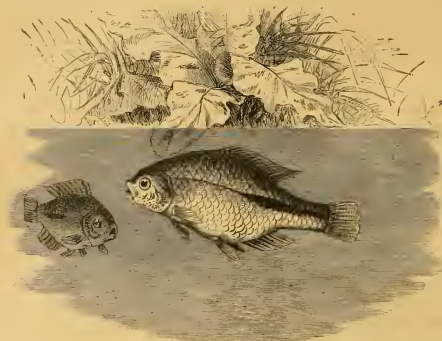
TENCH.

Austria, especially in the lakes; it is not abundant in the English rivers, but is often found in old pits in brick-yards, and muddy places generally. They are fattened on meal when preparing for table, and are a well-flavoured fish. The Tench is tenacious of life, and is usually brought alive to market in the midland counties. Tench have been taken thirty-three inches long, weighing eleven to twelve pounds. In the colder months this fish shelters itself in a hole which it excavates in the mud. In stocking Tench ponds two males should be allowed to every female. The eggs are deposited on weeds in June, and hatched in two or three days. There are three hundred thousand ova in a fish weighing four pounds.

In the genus *Chondrostoma*, which is well represented in Western Asia and Europe, the lower jaw has a sharp cutting edge over which there is a brown horny covering.

The ninth group is named *Rhodeina*. It is a small assemblage of fishes, some of which are from China and Japan, while the remainder are European. The most important genus is *Rhodeus*, well known on the Continent from the *Rhodeus amarus*, which has a silvery-bluish band on the middle of the tail, as in the Chinese species. It is sometimes found in warm springs. The female at the spawning time develops a remarkable tube external to the body, and often two-thirds as long as the fish. Down this tube the eggs pass, and specimens are sometimes seen in the Strasburg market with

the tube filled with yellow ova. After spawning, this appendage is gradually absorbed, till its former position is only indicated by a papilla.



RHODEUS AMARUS.

The tenth group is named from the typical genus *Danio*, *Danionina*. It has the lateral line on the lower half of the tail. The genera are distinguished by the form of the mouth, teeth, sub-orbital bones, and presence or absence of barbels. The species are mostly small, and are from the Indian region, though several occur in China and Japan, and one or two are from Western Africa.

The eleventh group rejoices in the name *Hypophthalmichthys*. It included only two species of Chinese fishes of the genus *Hypophthalmichthys*, which has the anal fin long.

The twelfth group, termed *Abramidina*, also has the anal fin long, but the abdomen, or at least part of it, is compressed into a sharp edge.

This is a somewhat large group of fishes comprising many genera. One of the best known is

THE BREAM.*

This is a species confined to the North of Europe, though also met with in the Pyrenees. It is distinguished by the compressed elevated form of its body, with a short blunt snout, and the dorsal fin is so placed that its last ray is above the beginning of the anal fin. The lateral line is low down on the side, and includes from forty-eight to fifty-two scales. There are twelve rows of scales above it and six below. The scales are pearly and the colour is whitish, but the slight yellow tinge deepens into brown with age. The pectoral and ventral fins have a reddish tinge, and the other fins are somewhat brown. The three vertebrae next to the head have no ribs, and may therefore be termed neck vertebrae; then follow fifteen abdominal vertebrae, carrying ribs, and there are twenty-one in the tail. The species abounds in England and Ireland in rivers, lakes, and canals, swimming in immense shoals. The spawn is deposited in May, when the eggs of a single fish number a hundred and thirty thousand. As many as four males follow one female when she is depositing the spawn. The fish is more valued for food on the Continent than in England. The usual size runs from two to four pounds, but large specimens reach a weight of fourteen pounds or more. The species is tenacious of life, and can endure great cold. It is reputed to be shy, and in Sweden in many parishes the church bells are not rung during the fishing season, for fear of driving the Bream away from the adjacent waters.

There are several other species found on the Continent which range southward to the Danube. The White Bream (*Abramis blica*) is a well-known British species which ranges from the Danube to Lapland. It is a smaller fish than the common Bream, and rarely exceeds a foot in length. Like most of the allied fishes, it feeds voraciously on worms, insects, and water-plants, and is itself largely preyed upon by the Pike. When it seizes the bait of the angler, it rises towards the surface, so that the float, instead of descending, lies flat on the water. It has fewer scales than the common Bream, there being nine rows above the lateral line and five below it. The colour is silvery-white, sometimes with a bluish tinge.

* *Abramis brama*.

The so-called Pomeranian Bream is regarded by Dr. Günther as a hybrid between *Abramis brama* and *Leuciscus rutilus*, having more in common with the Roach than the Bream.

THE BLEAK.*

This is a fish of much more elongated body than the foregoing. Its lower jaw projects beyond the upper jaw, which is protractile. The pharyngeal teeth are in two series, and hooked; behind the ventral fins the belly is compressed into a sharp edge across which the scales do not extend. It is a very active little fish, rarely growing to a greater length than seven inches; its back varies from a greenish to a brownish tinge, but the rest of the body is silvery-white and shining. This appearance is due to a pigment which exists on the inner surface of the scales, and is like that which gives brilliance to the Whitebait and Roach. This pigment has been utilised in the manufacture of artificial pearls, and in Paris is known as *Essence de l'Orient*. The scales are scraped off, washed, and triturated, when the pigment falls to the bottom of the water. Ammonia is added to separate the animal matter. The substance is then mixed with fish gelatine, and spread on beads of glass or plaster. At first the artificial pearls are almost, if not quite, equal in beauty to real pearls, but the pigment soon comes off on to the neck of the lady who adorns herself with them. In England the Bleak pigment was formerly largely used to wash over the cavities of thin glass beads, which were afterwards strengthened by being filled with wax. The use of Bleak for these purposes originated in Europe with the Venetians, in the sixteenth century, but the industry was prohibited by the Government. It was probably derived from China, where the art has been practised from time immemorial.

The East Indian genus, *Osteobrama*, has a large serrated dorsal spine, and a bipartite air-bladder. *Chanodichthys* is a genus from China and Formosa, which has the air-bladder tripartite, and, according to Dr. Günther, in one species at least has no liver. *Chela* is a genus with slender pharyngeal teeth, represented by many species in the East Indies.

The thirteenth group is named *Homalopterina*. It is chiefly distinguished by having no air-bladder. It includes four genera, which are from the East Indian region. The species are small.

The fourteenth and last group of the Cyprinidae, named *Cobitina*, has the air-bladder more or less completely enveloped in a bony sheath. The mouth is surrounded by not fewer than six barbels. The scales, when present, are small, and are sometimes entirely absent. In the genus *Misgurnus* the barbels are from ten to twelve in number, and the scales are more prominent than in other members of the group. The genus *Nemachilus*, however, has only six barbels; the best known example in Britain is the Loach (*Nemachilus barbatulus*). The air-bladder in this fish is small, and placed immediately above the entrance to the gullet in bony capsules, situate on each side of the bodies of the first two vertebrae. These capsules are circular, smooth on the inside, and have a slit on their outer margin, and are probably connected in function with the organ of hearing. Yarrell remarks that the parietal bones in the median line of the skull have an interspace between them, which in the living fish is occupied by cartilage. The length of the fish at its largest may be as much as five inches. It is covered with a slimy mucus secretion. It is widely distributed in Britain and Central Europe, but is not found in Scandinavia or Denmark. It frequents brooks and small shallow rapid streams, hiding itself under stones. In stormy weather this fish rises to the surface, apparently in expectation of the feast of insects then to be found on the surface of the water. The flesh of the Loach is everywhere esteemed as one of the greatest delicacies. All the members of the Loach family, especially this species, the Spinous Loach, and the *Misgurnus fossilis*, possess the remarkable habit of using the intestines as a supplementary breathing organ. Atmospheric air is swallowed, and, after passing through the intestines, is found to be largely charged with carbonic acid, but Siebold states that this method of respiration is only habitually used when the fish are in muddy waters. The caudal fin is truncate. The dorsal fin is in the middle of the body, and both these fins are marked with dark spots, arranged in cross bands. The back and sides of the body are marked with dark brown.

There are many species of this genus, ranging from the Lake of Galilee through Asia Minor and the Indian region. The *Nemachilus stoliczkae* is found in the Lake Tsomoriri, in Tibet, at a height of 15,500 feet above the level of the sea.

The Spinous Loach (*Cobitis tenia*) is a rarer fish in England, and is unknown in Ireland. It

* *Alburnus lucidus*.

especially affects muddy positions. It carries a small bifid spine below the eye, which is capable of being elevated by the fish at will. The body is considerably compressed; like all the allied fishes it emits sounds when touched. The length is about three inches; the barbels are remarkably short; there is a row of large brown spots on the side of the body, and a brown streak running from the eye to the end of the snout. It is less valued for food than the common Loach. This species, though characteristic of Europe, appears also to occur in Japan. In the genus *Botia* the air-bladder is divided into two parts; the anterior division is only partly contained in an osseous capsule, and the hinder portion is free and suspended in the abdominal cavity.

CHAPTER VII.

PHYSOSTOMI (concluded)—CYCLOSTOMATA—LEPTOCARDII.

GONORHYNCHIDÆ—HYODONTIDÆ—OSTEOGLOSSIDÆ—CLUPEIDÆ—THE ANCHOVY—THE HERRING—THE FISHERIES—THE BOAT and NETS—THE WHITEBAIT—THE SPRAT—THE SHAD—THE PILCHARD—THE PILCHARD FISHERY—CHIROCENTRIDÆ—ALEPOCEPHALIDÆ—NOTOPTERIDÆ—HALOSAURIDÆ—GYMNOTIDÆ—THE ELECTRIC EEL—ELECTRIC ORGAN—EFFECTS OF THE SHOCK—SYMBRANCHIDÆ—MURENIDÆ—CHARACTERS—VARIETY OF TYPES—THE SHARP-NOSED EEL—WEIGHT—HABITS—THE BROAD-NOSED EEL—THE CONGER EEL—CHARACTERS—PREHENSILE POWER OF ITS TAIL—HABITS—THE GENUS *Muraena*—PEGASIDÆ—CYCLOSTOMATA—CHARACTERS—MARSIPOBRANCHII—PETROMYZONTIDÆ—CHARACTERS—THE SEA LAMPREY—DISTINCTIVE FEATURES—GREAT SUCTORIAL POWER—DISTRIBUTION—THE LAMPERN, OR RIVER LAMPREY—THE SAND-PIPER—MYXINIDÆ—CHARACTERS—THE HAG—DISTINCTIVE FEATURES—REMARKABLE NOSTRIL CHARACTER—ITS ENORMOUS MUCOUS SECRETION—LEPTOCARDII—CIRROSTOMI—THE LANCELET—SIZE—CHARACTERS—PECULIAR HEART AND BLOOD—DIFFICULTY CONNECTED WITH IT AND HAG—FOSSIL FISHES.

FAMILY XVIII.—GONORHYNCHIDÆ.

This family contains only a single species, *Gonorhynchus greyi*, a marine fish found only at the Cape of Good Hope and in Australian and Japanese waters. It is covered with small spiny scales, and has barbels to the mouth; the dorsal and anal fins are both short; the air-bladder is absent. The large eye is covered by transparent skin; there are no teeth either on the jaws or on the palate, but patches of teeth are developed on the pterygoid bones and on the hyoid bone. It is about a foot long.

FAMILY XIX.—HYODONTIDÆ.

The Hyodontidæ comprise only the American fish termed the Moon-Eye (*Hyodon tergisus*), found in the fresh waters of North America, especially in the great lakes. It is covered with silvery cycloid scales, but has the head naked. The stomach is horseshoe-shaped, the body is oblong.

FAMILY XX.—OSTEOGLOSSIDÆ.

This is a small group of fresh-water fishes from the Tropics. The body in these large fishes is covered with scales, which are thick, and arranged like pieces of mosaic, though they are absent from the head, where the skin is almost entirely replaced by bone. The dorsal fin is on the caudal region, and opposite to the anal fin; sometimes both these fins are confluent with the caudal.

The genus *Osteoglossum* is found in the fresh waters of Queensland, the Indian Archipelago, and Tropical America. *Arapaima gigas* is a large fish from Brazil and British Guiana. The head is less than one-fourth of the total length. Specimens in the British Museum are eight feet long, but it is sometimes nearly twice that length, and weighs 400 lbs. It is often captured with the hook, but frequently killed by the Indians with the bow and arrow. A number of men and boys go out in small boats, and when the fish is seen shoot at it. Of course it instantly disappears, but is followed up and shot at again and again, till, at length becoming exhausted, it is easily captured. The flesh is not very appetising, but is salted and dried by the natives and exported. In the allied *Heterotis niloticus* of Tropical Africa the stomach consists of two distinct portions, one membranous and the other muscular; the air-bladder is cellular, and the fourth branchial arch carries a spiral organ. These fishes are often three feet long.

FAMILY XXI.—CLUPEIDÆ.

This family is scarcely inferior in importance to any other group of fishes in the supply of human food. Its varied forms have led the family to be subdivided into seven groups, comprising in all more

than 150 species. These fishes are widely distributed in all seas, especially on coasts, and many of the species enter rivers. In all of them the head is naked and the body covered with scales; the maxillary bones are formed of three pieces, which are sometimes movable, and constitute the lateral parts of the jaws, the pre-maxillaries forming the middle part in front. The stomach is furnished with a pouch, and there are numerous pyloric appendages. The pseudobranchii are large, except in one genus, *Megalops*, where they are rudimentary or absent. In the first group, termed *Engraulina*, the pre-maxillary bone is remarkably small and firmly united to the maxillary; the upper jaw projects, and the mouth is wide. The best known member of this group is

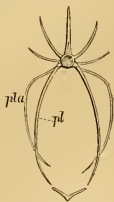
THE ANCHOVY.*

This is a fish with an elongated body and pointed snout, which projects well beyond the lower jaw. The teeth in the maxillary bone are very small; and there are teeth on the vomer, palatine bones, and pterygoids. The abdomen is rounded, and, like the sides of the body, silvery. A black stripe divides the colour of the sides from the dark tint of the back. The tail is forked. The species is widely distributed on the European coasts, and especially all through the Mediterranean and Black Sea. It is met with in the English Channel, and has been taken in the Thames and at Yarmouth. It occasionally visits Norway and the Baltic and Davis Straits. A variety of this fish ranges into the South Pacific, being taken in Tasmania and New Zealand. The greatest length of the Anchovy is eight inches. Most of the Anchovies consumed in England come preserved in oil or salt water, and they form the principal, though not always sole, ingredient in anchovy sauce. They are taken in immense numbers on the coasts of Spain, France, and Portugal from May to July, when the fish has come into the Mediterranean from the Atlantic, to which it is believed to return after depositing its spawn. Fishing is carried on at night, when the fish are attracted by lights, and then the seine-net is spread round the spot where they have congregated. Couch is of opinion that a sufficient quantity of Anchovies might be taken in British waters to supply the demand in England if the fishing were carried on in a proper way. Several species of the genus are taken in the rivers of South America, but the genus is best represented in the West Indies and adjacent coast, and in the East Indian region. Forty-three species of Anchovies are known. The second group of the Clupeidae is termed *Chatoëssina*. It has the narrow mouth toothless and the abdomen serrated. The species occur on the coast and rivers of India, China, Australia, and North and Central America.

The third group, *Clupeina*, has no conspicuous difference in the length of the jaws, and the abdomen is serrated. It includes a multitude of species chiefly referable to the genus *Clupea*. They inhabit the shores of every part of the world, and many species are found in rivers.

THE HERRING.†

This species is widely distributed in the North Atlantic, both on the European and American shores, and extends along the northern coast of Asia. Herrings have been found plentifully in Delaware Bay, and occur both in the Black Sea and, according to some writers, in the Caspian, though the latter specimens are probably the well-known *Clupea caspia*, which is limited to the Caspian, and is intermediate between the Herrings and the Shads. Large examples of Herring may be fifteen inches long. The fish is too well known to need a detailed description. The accompanying figure shows the spinous processes and ribs (*pl*) of this fish. There are about twenty pyloric appendages to the stomach. It feeds chiefly on the more minute crustacea, but many kinds of young fishes have been found in its stomach. In the Outer Hebrides, which is one of the great fishing stations for the Herring, the fishery is forbidden by law before the 20th of May; but in the Shetland Isles the fish do not commonly appear in any number till July. On the east of Scotland they abound in August, September, and October. In the West of England they are usually plentiful in October and November, but in some years appear earlier or continue later. Nothing certain is known of the cause of the migration of the Herring, and from time to time it changes its course, so that many years may elapse without its ever being seen on coasts which it formerly frequented. The numbers taken, however, are almost incalculable. In Scotland alone half a million of



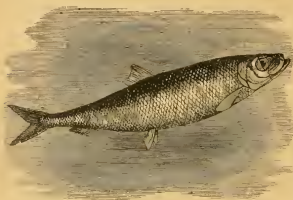
VERTEBRA OF HERRING. (After Owen.)
pl, Rib; *pta*, spinous process of rib.

* *Engraulis encrasicolus*.

† *Clupea harengus*.

barrels are said to be prepared for exportation every year. Each barrel contains 550 full-grown fish. The female contains about 70,000 eggs, and spawns in the early part of November. The spawn is deposited on the sea bed, and is discharged in a mass, which adheres firmly to the rocks. The young are found abundant in a fortnight to three weeks, and in six weeks are three inches long. The Herring fishery dates back to Anglo-Saxon times, when towns on the east coast paid their taxes in Herrings. Yarmouth cannot be said, like Amsterdam, to be built on herring bones, but is a well-known centre of Herring industry. The charter of the town requires the corporation to deliver to the sheriffs of Norwich a hundred Herrings baked into twenty-four pasties, that they might be delivered to the lord of the manor of East Carlton. The fish are easily alarmed by noise, and rush away to a distance of five or six feet, but rarely spring in the water like Pilchards. The fish are usually sold to professional curers, who prepare them in a variety of ways, which are well known in Britain, and the curing alone gives employment to many thousands of people. On the continent the Herring is also highly prized, and sometimes is preserved moist, with spices, salt, and other condiments, and is often eaten uncooked.

The Herring fishery is usually carried on by means of the drift-net, which is made of cotton or hemp twine. These nets are largely made at Bridport. The cotton nets are the more flexible, and are



HERRING.

prepared for use by being first soaked in linseed oil, and then either boiled in oak-bark liquor for two or three days, or a preparation of catechu, but they are sometimes dressed with coal-tar instead. The net consists of one piece, which is thirty yards long. It is fastened to a small line about eighteen or twenty yards long, so that the netting is slack. The back of the net is fastened at short intervals to a small double rope, which encloses pieces of cork, so as to keep that part of the net uppermost. A single vessel, according to her size, may use from eighty to a hundred and thirty of such nets. They are connected together in succession, and often extend for a length of a mile, or a mile and a quarter. The meshes are about an

inch, or rather more, in diameter, but in old nets the size becomes less. The twine nets last longer than those of cotton, are generally barked once or twice in the season, but never tarred. A fishing boat carries two sets of nets—one with many cork floats, to be used when the fish are near the top of the water, and the other with few corks, which is used when the fish are swimming at some depth. The whole of the train of nets is made fast to the vessel by a moderately strong rope, technically called a warp. These nets are used almost entirely at night. The vessels employed are all small, the largest being about thirty-six tons. The number of men in the larger boats is usually from nine to eleven. When the fish are plentiful the nets remain but a short time in the water—are hauled in and shot out again. The fish, when got on board, fall on the deck, are sprinkled with salt, and are stowed away in compartments called the “wings” of the hold. If fish have been plentiful the mast is put up when the night's fishing is over, the vessel makes sail, and returns to port; but if fish are scarce, the smack seeks fresh ground for another night's work. Good fishing ground is generally indicated by the abundance of sea-birds, Dog-fish, and Cetacea, which follow the fishes, and feed upon them. Some tropical species of Herring are poisonous.

A good deal of difference of opinion has prevailed as to whether the Whitebait is a distinct species. Yarrell believed it to be distinct, as do Jenyns and Couch, but Dr. Günther remarks emphatically that all the examples of Whitebait that he has examined are young Herrings.

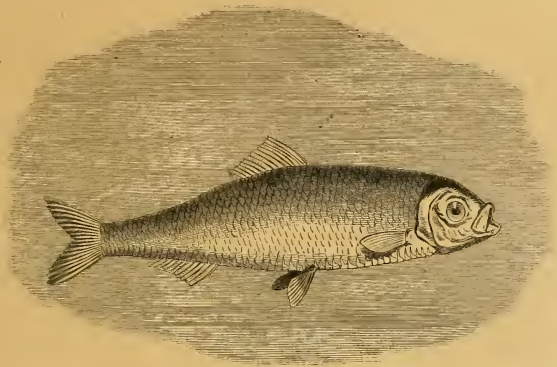
This fish is taken in the Thames from April to September, and abounds especially off the Northern coast. The net with which they are caught has a mouth about three feet square. The bag-end of the net is very narrow, and the mesh of the net is very small. The boat is moored in the tide-way, where the water is from twenty to thirty feet deep. The small end of the net is from time to time taken into the boat and untied, when its contents are shaken out.

The Sprat (*Clupea sprattus*) is a very distinct species from the Herring. It is well known on the

Atlantic coast of Europe, and extends into the Baltic and western half of the Mediterranean. It does not appear to take the hook, and is usually captured with the stow-net, the meshes of which must not be less than half an inch from knot to knot. The quantity caught far exceeds the demand, and in many localities they are used for manure. The Sprat, when full grown, is six inches long, but its ordinary length is three inches. The scales are smooth, and are easily shed. The lower jaw is prominent. There is an oval patch of small teeth on the tongue. The abdomen is serrated in front of the ventral fin, as well as behind. The tail is deeply forked.

In the Baltic it is preserved with spices, and eaten as a relish for lunch. There are from forty-seven to forty-nine vertebrae in the Sprat. In the Herring there are fifty-six. Other species occur in the Mediterranean, West Indies, United States, Indian Archipelago, China, and Australia.

The Shad (*Clupea alosa*) is commonly called the Alice Shad. It is especially distinguished by having from sixty to eighty long, very fine gill-rakers on the horizontal part of the outer branchial arch.



SPRAT.

It is frequently met with on the European coasts, and occurs in the Mediterranean. The flavour improves after they have been some time in a river. Excellent Shad are found in the Severn, where they are caught in April and May. It occasionally is taken as high up as Worcester. At sea it is often caught on lines with a Mackerel bait. It sometimes reaches as great a length as four feet: two feet is a commoner size. It is a fish deeper in the body than the Herring. The back is blue and the belly silvery, becoming more or less reddish. The closely allied *Clupea finta* has about five-and-twenty stout osseous gill-rakers on the horizontal part of the outer branchial arch. In Great Britain it is usually known as the Twaite Shad. It enters the rivers in May, and returns to the sea by the end of July. Its ordinary length is from twelve to sixteen inches. It is found in the Nile.

The Pilchards (*Clupea pilchardus*), distinguished by radiating ridges on the operculum, especially frequent the Mediterranean, and adjacent parts of the Atlantic, and extend northward to England and Sweden, but rarely wander into the Bristol Channel, or as far east as the Straits of Dover. They are never absent from the coast of Cornwall, though in winter the fish keep near to the bottom. In spring they begin to congregate, and in July the great shoals are met with. The fishery, with the seine-net, begins in August, and lasts till the rough weather of the equinoctial gales puts an end to it. Some Pilchards spawn in May, others in October; but there is no reason for suspecting that they spawn twice in the year. Yarrell found that their stomachs are often crammed with a small

species of shrimp no larger than a flea. Couch believes that the spawn is shed on the surface of the water, and remarks that after spawning a sheet of jelly, full of eggs, has been seen extending for several miles in length, and fully a mile in breadth, over the surface of the water, but no thicker than brown paper, and so tough as not to be easily torn.

The French fishermen endeavour to attract the Pilchards to the drift-nets, which they use, by scattering the salted roe of Cod and Ling. It is said that the fish are so easily alarmed by noise that the firing of a cannon at a distance of twenty miles has caused them to sink into deeper water, hence all the proceedings of the fishermen are arranged by signs. The Pilchard is sometimes eleven inches long; it is a thicker and smaller fish than the Herring. The upper part of the body is bluish-green, and the belly and sides silvery-white. It is largely cured for exportation. Dr. Günther distinguishes two varieties, first, the Sardine of the Mediterranean, and secondly, the Pilchard of Cornwall.

The Pilchard is closely represented on both sides of the Pacific by a variety named *Clupea sagax*.

The seine-net appears to have been used from the earliest times in the Pilchard fishery. It is used to surround the fish in the sea when they appear in shoals. In the Pilchard fishery two or three nets are sometimes used in enclosing the shoal. The principal net is about 200 fathoms long, and ten fathoms deep. To this seine another net is united, which is 100 fathoms long, and is called the stop-seine. There is a boat with each net, and, starting from the same place, the boats move in different directions. The seine is carried outside the shoal parallel to the shore, and brought round towards it by these boats. The stop-net is then shot out towards the land across the direction in which the fish are moving, so as to intercept them. The end of this net is then brought round towards the large seine, and the circle is completed. The stop-nets, if more than one has been used, are afterwards taken out, and the seine is drawn towards a quiet part of the shore, till it grounds, and is moored. The fish are removed from this net with a smaller one called the tuck-seine, which, however, may be seventy or eighty fathoms long, and eight to ten fathoms deep. It is so placed as to get the net under the fish, when they are brought to the surface, put in baskets, and taken on shore. At St. Ives, in Cornwall, the Pilchards are sometimes taken in such quantities that several days may be required for landing the fish from a single net. The Oil Sardine is caught on the east coast of India.

The fourth group of the Clupeide is named *Dussunierina*. It is a small assemblage of fishes, chiefly found in the East Indies, though one or two species occur on the Atlantic coasts of America.

The fifth group, *Albulina*, is formed for the *Albula conorhynchus*, a fish with a conical snout, of a uniform silvery appearance, a compressed oblong body, and flat abdomen. It ranges throughout the tropical and sub-tropical seas, being found in the Atlantic, Indian Ocean, and Pacific.

The sixth group (*Elopina*) has the upper jaw shorter than the lower, and with a narrow osseous plate covering the space between the mandibles. It includes the genera *Elops* and *Megalops*, both found in tropical and sub-tropical waters. The two species of *Megalops*, both five feet long, enter rivers.

The seventh group, called *Chanina*, has no teeth. It includes only the two species of the genus *Chanos*. In this genus the mucous membrane of the oesophagus is raised into a spiral fold.

FAMILY XXII.—CHIROCENTRIDÆ.

This family comprises the one species *Chirocentrus dorab*, three feet long, in which the air-bladder is incompletely divided into cells. It occurs in the Indian Ocean and Archipelago from Africa eastward, and in the Chinese and Japanese Seas.

FAMILY XXIII.—ALEPOCEPHALIDÆ.

The type of this family is the *Alepocephalus rostratus*, a deep-sea fish from the Mediterranean, in which the air-bladder is absent. Externally it is of a blackish-brown colour, and is remarkable for having the inside of the mouth and abdominal cavity black. Three other genera are known.

FAMILY XXIV.—NOTOPTERIDÆ.

This family comprises the genus *Notopterus*, which is distributed in the fresh waters of India and the Indian Archipelago, and has two species on the west coast of Africa. The tail in this type is long and tapering, the anal fin is very long, the air-bladder is divided in the interior, terminating at each end in a pair of horns, those in front being connected with the auditory organ.

FAMILY XXV.—HALOSAURIDÆ.

This family has but one genus, the *Halosaurus*. Both body and head are covered with cycloid scales; the long body terminates in an exceedingly long tapering tail; the snout projects far beyond the mouth. There is only one and a half series of scales between the lateral line and the ventral fin. *Halosaurus oweni* is found at Madeira. Other species range down to a depth of 2,750 fathoms.

FAMILY XXVI.—GYMNOTIDÆ.

This family includes a small assemblage of fishes having a long eel-shaped body, a long anal fin, no ventral fin, and a tapering tail, the extremity of which is capable of being reproduced.

The ribs are well developed, the air-bladder is double, and the vent is near to the throat. All these fishes are confined to the fresh waters of the tropics, abounding in Brazil and the Guianas. Only one member of the family—the Electric Eel (*Gymnotus electricus*)—possesses electric properties. It is the only species which is entirely devoid of scales; it possesses a single row of conical teeth; the dorsal and caudal fins are entirely absent, but the anal fin is prolonged to the end of the tail.

The electric organ is placed on each side of the lower part of the tail, reaching forward to the vent, and forming a third of the weight of the animal. The colour of the fish is blackish above, but the belly is of a paler and reddish tinge. Ill-defined spots frequently extend along the back and sides. The length varies from three to six or seven feet. The experience of observers has varied as to the effects of the electric power of the fish, but it seems to be agreed that if it be picked up by the tail sensations of an acute and painful character are felt and do not immediately pass away. It is well known that cats and dogs perform remarkable feats of a gymnastic character after the incautious examination of this animal. It is shunned by the other inhabitants of the river, and dreaded by the Indians, who, nevertheless, overcome their scruples when the animal is dead, for the muscles are accounted palatable, though the flavour of the electric organ is unpleasant.

The shock is said to be sufficiently powerful, in the case of large fishes, to paralyse horses and kill small animals, and is much more severe than the shock from the torpedo. The discharge takes place apparently under the action of the will. In South America wild horses have been driven into the rivers by parties travelling, so that the fishes might exhaust their energies on the horses before the men ventured in the water. The fish sometimes die from excessive exhaustion, but usually regain the electric energy in a few hours. The two ends of the fish are in opposite electrical conditions, so that the most powerful shock is received when contributed to by the head and tail of the fish. The electric nerves are very numerous, and belong partly to the fifth pair, and partly to the intercostal series.

The Electric Eel does not often eat the fishes killed by its shocks.

The other genera in this family are all covered with scales. *Sternarchus* has the tail terminating in a small caudal fin, and there is a rudimentary dorsal fin attached by a band of fat to a groove in the back of the tail; but in *Rhamphichthys*, *Sternopygus*, and *Carapus* the tail terminates in a free point. Several species of the genera *Sternarchus* and *Rhamphichthys* have the snout produced into a more or less long tube.

FAMILY XXVII.—SYMBRANCHIDÆ.

This is a small and varied group of Eel-like fishes, which have the body naked or only covered with minute scales; the upper jaw is entirely formed by the pre-maxillary bones, the maxillary bones being placed behind them in a parallel position.

There are no pectoral or ventral fins, and all the vertical fins are reduced to little more than membranous folds. There is no air-bladder, and there are no pyloric appendages to the stomach. All these fishes are found in tropical regions; the first group, *Amphipnoia*, is formed for the Bengal species *Amphipnoides*. It has the vent in the posterior half of the fish's length, and is covered with minute scales; the palatine teeth are in a single series, and there is an air-sac communicating with the gill-cavity. There are one hundred and six vertebrae in the abdomen and sixty-five in the tail. It is found in Bengal.

The second group, *Symbranchina*, includes the genera *Symbranchus* and *Monopterus*, both naked fishes, and neither possesses the accessory breathing sac. *Monopterus* is from the East Indies and Japan; *Symbranchus* has a species in tropical America and another in the East Indian region. The third group of the family, named from the typical genus, has but one species—*Chilobanchus*

dorsalis—a small fish, found in Australia and Tasmania. It has the vent in the anterior half of the body, the stomach is large, there are no teeth on the palate, and those on the jaws are in single series.

FAMILY XXVIII.—MURENIDÆ.

The Murenidæ are a large group of fishes, presenting no small amount of variation in the details of their structure. The long body is sometimes cylindrical and sometimes compressed like a band. In certain genera it is naked, in others defended with rudimentary scales. Both maxillary and pre-maxillary bones carry the teeth in the upper side of each jaw, and the ventral fins are always absent. Dr. Günther groups the genera into two sections, the first distinguished by the branchial openings into the pharynx being wide slits, while in the second group those slits are narrow. The former group is the more important, and includes the majority of the genera.

The first type in the family is the *Nemichthys scolopacea*, in which the body is band-shaped, and the tail exceedingly long and tapering to a point. The vent is near to the root of the pectoral fins, the jaws are elongated into a slender bill, the inner surface of which is covered with small teeth, which are little more than asperities.

The dorsal fin commences behind the head. This fish occurs in the Atlantic. A specimen thirty-three inches long has the head three inches long.

The second type has the tail longer than the trunk, the bones are thin, and the muscular system is moderately developed. It is represented by the single species *Saccopharynx flagellum*, which Dr. Günther describes as a deep-sea Conger Eel. The snout is very short and the gape immense. The stomach is capable of being distended to an amazing extent; the vent is at the extremity of the trunk. This fish is known from Madeira and adjacent parts of the Atlantic. It is perfectly black, and reaches a length of about nine feet, the greater part of which is formed by the tail.

The third type is furnished by *Synaphobranchus pinnatus*, a deep-sea fish from Madeira, with a scaly body, wide gape, extensible stomach, and well-developed fins.

The fourth type is characterised by having a fin surrounding the end of the tail. It includes such genera as *Anguilla*, *Conger*, *Congromurena*, and *Uroconger*.

In the genus *Anguilla*, or true Eels, small scales are imbedded in the skin, the teeth are arranged in bands, and the dorsal fin does not extend forward to the back of the head. The Eels range all over the world, except into the Arctic regions. The *Anguilla bengalensis* extends through the rivers of the Indian Continent; the Fiji Islands contribute a peculiar species from three to four feet long; the north-east of Australia, and the Zambesi, Amboyna, the Seychelles, and many other localities have their characteristic forms; while others, like the *Anguilla australis*, range over a wide area, as from New Zealand to Timor, or, like the *Anguilla hostoniensis*, range from Boston to China and Formosa. The best known of the Eels is the common European species.

THE SHARP-NOSED EEL.*

The ordinary weight of a large Eel is about four pounds, but examples have been caught in the Medway weighing as much as from thirty-five to forty pounds, and measuring six feet in length. Couch, indeed, instances a printed record of an Eel that weighed sixty-two pounds, but confesses his doubts as to the statement being trustworthy. The form of the Eel is very similar to that of a Snake. The fish inhabits most of the rivers, ponds, and lakes in England, and especially abounds in the Cambridgeshire fens, where in monastic times it was often a principal item of food. Eels for the London market are largely imported from Holland. The common Eel has been kept in confinement for at least thirty years; it lies torpid in the winter, and though it may move on the bottom during fine days, takes no food. They eat but little in the spring, but as soon as the warm weather begins develop an almost insatiable appetite, subsisting chiefly on worms. They become quite tame, and take food from the hand. Towards autumn, they often leave the water, but by the beginning of September retreat to their winter resting places under the stones. When in the rivers, the adult Eels make an autumn migration, probably for the purpose of depositing the spawn, but it is uncertain whether they go merely into brackish water or far out to sea. There is also a spring migration, and most writers concur in stating that at this time the young Eels travel up the streams. During the cold part

* *Anguilla vulgaris*.

of the year Eels frequently bury themselves in the mud, sometimes to the depth of a foot or more, and on the banks of many rivers they are easily dug out when in this torpid condition. Eels are highly excited and restless during electrical disturbances in the air. Yarrell states that though absent from cold countries, they may remain on the ground till frozen, be buried in the snow for days, and then recover perfectly when put back into water. The spawning has never been observed. They sometimes attack other fishes, especially the Carp, and consume immense quantities of spawn and fry, and when no other food is available will eat each other. Rats and Snakes have been found in their stomachs. The vent includes four distinct openings, two of which are for the discharge of the roe. The air-bladder tapers at each end, and has two short branches in front. The lower process, like the posterior extremity of the air-bladder, is cellular, and the bladder also contains several transverse partitions. In the tail there is a pulsating lymphatic heart, similar to those which have been described in Frogs and other Amphibia. Examples of this Eel have been found in the Nile, Palestine, Algiers, Madeira, in the Mediterranean, and in North America.

THE BROAD-NOSED EEL.*

This species is even more widely distributed than the Sharp-nosed Eel, since it occurs throughout Europe, in the West Indies, New Zealand, China, and the Nile. It presents many slight varieties, and is characterised by the broad and fleshy lips and the comparatively wide head. This Eel is sometimes called the Grig. It rarely weighs more than five pounds, but is thicker in proportion to the length than the Sharp-nosed Eel, and is said to give a more greasy sensation to the hand. It has no peculiar habits. These two species are the only European Eels.

THE CONGER EEL.†

The Conger Eel has no scales; the mouth is wide, and the teeth are arranged in rows, one of which is so closely packed as to form a sharp cutting edge. The vomerine teeth reach backward nearly to the tip of the tongue. The biting power of the fish is extraordinary, for Yarrell mentions that he has found in the stomach the finely-comminuted shells of Mollusca; but they do not always divide their prey, for in the stomach of a large fish a young Conger was found, three feet long, in company with some Dabs. Congers grow to a large size, and may reach a length of ten feet and a weight of a hundred and thirty pounds. The flesh is chiefly eaten by the poor, but when dried and grated it is made into excellent soup.

In Cornwall, where they are most abundant, the fish is usually taken on dark nights, on short or long lines baited with the Pilchard. They often live among rocks; those from such positions are uniformly black, while in sandy places they may be white or ash-coloured. Among the odd contents of the stomach, Couch records Soles and Plaice, Skulpins and Weevers, Lobsters, Hake, Pilchards, Herrings, and Cuttles. Their digestion is so rapid that when a hook is swallowed it is soon dissolved. One of the most singular habits of the fish results from the prehensile power of the extremity of the tail, which is capable of being used like a hand, for it has often been known to grasp the gunwale of a boat with it and leap over into the sea. A habit no less remarkable is its power of rapid rotation about its own axis, which has been exercised upon incautious thumbs and toes which fishermen have inserted into its mouth. The fish is sensitive to cold and to east winds. It is met with between the shore and a depth of fifty fathoms. The colour is usually pale brown above and dull white on the belly, with a white lateral line. The dorsal fin begins opposite to the extremity of the pectoral fin. The skeleton is distinguished from that of the common Eel by the longer transverse processes, which extend down the tail, but in the genus *Anguilla* transverse processes are wanting in that position. It is found round the coasts of Europe, in the Mediterranean, South America, Tasmania, East Indian Archipelago, and Japan. It spawns in December or January.

The fifth type of this family includes scaleless Eels of the genus *Heteroconger*, which have the tail compressed, the snout short, the lower jaw projecting beyond the upper, and no pectoral fins.

The sixth group has for its type the genus *Muraenesox*, in which the jaws have canine teeth. The species are found in tropical seas, chiefly in the East and West Indies. The allied genus, *Nettastoma*, is from the Mediterranean and Japan.

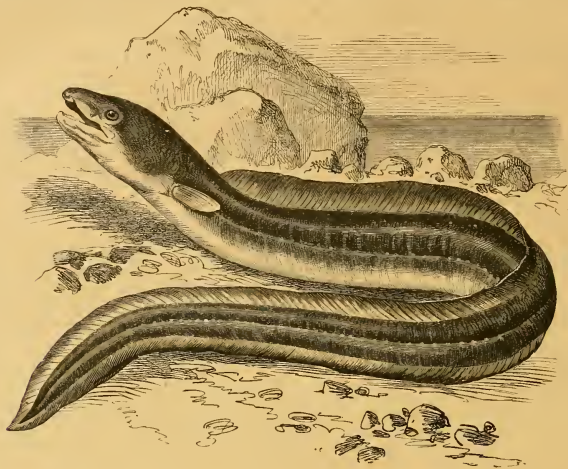
* *Anguilla latirostris*.

† *Conger vulgaris*.

The type of the seventh group is the genus *Myrus*, in which the nostrils are upon the margin of the upper lip, and the tongue is fixed as in the preceding group.

In the genus *Muraenichthys* the body is long and worm-like, and without pectoral fins. The species frequent the Indian Archipelago.

The eighth group chiefly comprises the species of the genus *Ophichthys*, which are very numerous. The nostrils are placed as in the last group, but the extremity of the tail is not surrounded by fins. In some of the species, such as *Ophichthys quadratus*, from China, the tail is four-sided, and the dorsal and anal fins are absent. The pectoral fins present all degrees of development; the teeth, too, are very variable, and in some species, like *Ophichthys boro*, they are granular. This species occurs in both the



CONGER EEL.

fresh waters and seas of the East Indies, and apparently has been met with in the West Indies also. Other species have the lips fringed.

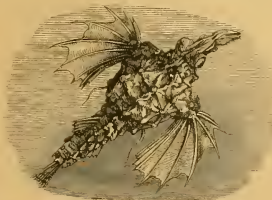
The ninth group comprises the genus *Moringua*. It has the tail much shorter than the trunk, and the heart situated far behind the gills, and as in so many of the Eels the gill-openings are narrow and on the under side. The species occur in the East Indian Islands, but range to Japan. There are about ninety vertebrae in the body and forty in the tail.

The tenth group has the genus *Muraena* for its type. It contains a very large number of species, which are all without scales and have no pectoral fins. The teeth vary a good deal with age, as the series are more numerous in the young than in the adult. In a good many forms the teeth are sharp, in others, feeding on crustacea, they are blunt and have the character of grinders. Some species have the posterior nostrils tubular. The ornamentation may consist of spots, which are brown or black, round or polygonal. Sometimes there are black cross-bands, while other species are ornamented with a network of yellowish lines. The *Muraena macrurus*, which reaches a length of fully ten feet, has the tail twice as long as the body. The *Muraena richardsonii*, another Indian type, has the skin folded, with the folds crossing each other so as to form pouches. The *Muraena undulata* is incapable of completely shutting its mouth.

The orbit in this genus is generally formed by a complete bony ring. Certain fishes have been described under the name *Leptocephalus*, which Dr. Günther regards as larval forms, for they have the notochord unossified and the eye large, and other evidences of imperfect development. It would hence appear as though some of the Congers passed through a sort of metamorphosis, and this condition may characterise the genera *Myrus*, *Ophichthys*, and *Murena*. In these fishes there is never any trace of reproductive organs, no air-bladder, the vent cannot always be discovered, the stomach has a large blind sac, and the straight intestine runs close to the abdominal surface. When any ossifications occur they are always towards the end of the vertebral column. There are no ribs; the skull is cartilaginous; but both jaw-bones sometimes contain a little bony matter. Gelatinous substance usually occurs between the muscles and the notochord, and the same substance divides the lateral muscles from each other. The forms with a cylindrical body have red blood, but those with a flat body have the blood but faintly coloured.

FAMILY XXIX.—PEGASIDÆ.

This family is represented by the one genus *Pegasus*, a group of small sea-fishes from the Indian and Australian seas. It may belong to the *Acanthopterygii*, for the body is entirely covered with bony plates, which are blended together on the trunk, but form rings on the tail, and they resemble the *Cataphracti* in this and other characters. The plates on the tail are movable. The gill-cover is a large plate formed of the opercular bones blended together, though the inter-operculum is a delicate bone lying below it. The snout is greatly elongated; the mouth is toothless. The bony ring below the eye is well developed. The vertebrae are thin, and there are no ribs. The pectoral and ventral fins, Dr. Günther remarks, have more of the *Acanthopterygian* than *Physostomatous* character. They are from India, China, and the Australian coasts.



PEGASUS DRACONIS.

DIVISION III.—CYCLOSTOMATA * (FISHES WITH A CIRCULAR MOUTH).

The third great division of fishes is a small one, much lower in organisation than the groups which have been already described, and belonging to an altogether distinct type. The vertebral column is represented by a notochord, upon which the skull is not movable. The whole skeleton is cartilaginous, and there are neither ribs, jaws, nor limbs. The mouth is margined by a circular lip, and is suctorial. The intestine is straight, without appendages of any kind. The form of the gills has suggested the name *Marsipobranchii* for this order of fishes, for they are purse-like organs, with a number of lateral apertures which somewhat resemble the gill-openings of Sharks, except that they are usually small and more or less circular. The heart is formed on the plan usual in fishes, but the *bulbus arteriosus* was long overlooked, and its existence is sometimes denied. The brain is small and fish-like, and quite distinct from the spinal cord. The nostril is a single tube in the middle line of the head.

ORDER MARSIPOBRANCHII.†

FAMILY I.—PETROMYZONTIDÆ.

The fishes of this family are commonly known as Lampreys. They have the body shaped like that of an Eel, are naked, and undergo a sort of metamorphosis. The larval form was long supposed to be a distinct fish, and named *Ammocoetes*. The head is then very small, the upper lip is semicircular, and the lower lip, which is separate, is small, and the mouth is toothless and surrounded by fringed barbels; the eye is small and hidden in a groove. The vertical fins extend round the body as a continuous fringe. It is not till the third or the fourth year that the fishes undergo the

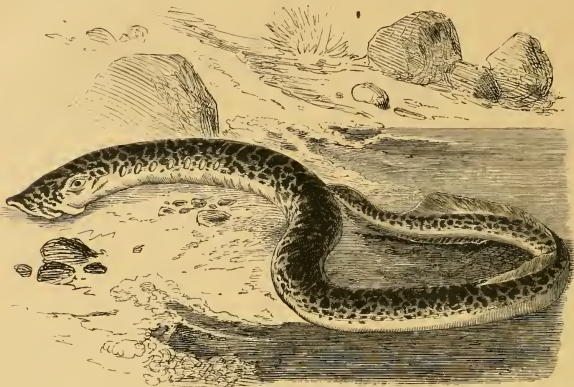
* *kuklos*, circle; *stoma*, mouth.

† *marsipos*, pouch; *branchia*, gills.

metamorphosis and attain complete development. In the adult, as in the young, there is only a single nostril on the upper side of the head. There are seven branchial sacs. The intestine has a spiral valve.

THE SEA LAMPREY.*

The Sea Lamprey commonly attaches itself by the mouth to stones and rocks. The mouth is full of small teeth. The maxillary teeth are two in number and united together; in the lower jaw there is a single crescent-shaped tooth-plate, with from seven to nine cusps. The other teeth are arranged in rows, which cross each other obliquely, and more or less cover the whole surface of the mouth and throat; some of them are bicuspid. They often attach themselves to the bottom of a boat or ship, and the air is so perfectly exhausted that a fisherman is sometimes unable by sheer strength to pull the fish off. Couch records that the young Lamprey often attaches itself to the Mackerel, Gurnard, Coal-fish, Cod, and Haddock, rasping considerable holes in the flesh with its suction teeth, and he states that



SEA LAMPREY.

instances have come under his notice in which wounds evidently made in this way have afterwards healed. The spawning time of the Sea Lamprey varies a little in different countries, but in England the spawn is deposited in April and May, when the fish ascend rivers. They are then in the finest condition, and are caught at night. The male and female fish prepare a groove in the bottom of the river, in which the eggs are placed so as to be covered with sand. Yarrell states that the roe escapes by a membranous sheath, the internal face of which has five apertures. The fish has always been valued for food. In England it is chiefly taken in the Severn, though sometimes met with in the Thames and many other rivers. It is found in the Rhine as far up as Basle, in nearly all the rivers of France, in the Rhone, and the Italian rivers which empty into the Adriatic and the Mediterranean. According to Siebold, it occurs on all the coasts of Europe excepting those of the Black Sea. It ranges southward to the west coast of Africa, and is found in North America. The Sea Lamprey usually measures less than three feet in length.

The first dorsal fin is well separated from the second dorsal fin. Both are placed on the hinder part of the body. The colour is a greenish-brown, marbled on the sides and back with darker tints of brown and green. It swims with lateral movements of the body, but commonly remains on the bottom. The mouth shuts laterally instead of vertically.

* *Petromyzon marinus*.

THE LAMPERN, OR RIVER LAMPREY (*Petromyzon fluviatilis*).

In the River Lamprey the skull is cartilaginous below, and in front carries a considerable mass of labial cartilages. The neural arches may be represented by cartilages. The maxillary tooth has a broad base with a cusp at each extremity, and the mandibular tooth is a corresponding plate with seven to nine cusps, which are relatively smaller than in the Sea Lamprey. It is a much smaller fish than the latter, and is commonly from a foot to fifteen inches long. It lives on insects, worms, and small fishes. It abounds in the Thames, from which formerly a million Lampreys were taken in a year. It is met with in the Severn, and has a wide distribution in the rivers of Europe, and occurs in some of the lakes of North Italy. It is also found in North America and Japan. The ovaries, according to Heckel and Kner, extend the entire length of the abdomen. The intestine does not enlarge into a true stomach. This fish is chiefly valued for bait, being tenacious of life, so that it can be kept alive at sea for some weeks. It is sold at from £3 to £5 a thousand. When pickled, it is imported from Holland for the German inhabitants of Soho. The colour is dark bluish on the back and silvery on the sides.



RIVER LAMPREY.

THE SAND-PIPER (*Petromyzon branchialis*).

This species is often called the Fringe-lipped Lamprey, because the circular lip is furnished with numerous papillæ. It is shorter and relatively thicker than the River Lamprey. Its teeth are much blunter, but otherwise similar to those of *Petromyzon fluviatilis*. The dorsal fins are deeper, but separated by a notch. It is common in the rivers of Europe and of England, and occurs in the western parts of North America. Its habits are very similar to those of the other fresh-water species, which it resembles in colour.

The young of this species is sometimes called the Mud Lamprey, or "Stone Grig." The upper lip is then remarkable for its horseshoe shape; the mouth is incapable of adhering to stones. The fish hides in the mud and loose sand at the bottom of brooks. It is said to be devoured in great numbers by the Eel. The eggs are hatched in eighteen days, when the young fish are white. At first there are eight branchial slits, but the front one soon disappears. Before the mouth comes into existence there is an oval vesicle in its place, and there is no separation in the young between the alimentary canal and the branchial organ. The respiratory canal is usually not completed till the end of the fourth year, when the metamorphosis takes place, occupying a period of about ten days. The teeth then develop, the intestine becomes shorter, the eyes become more perfect, and the Lamprey's food is changed from microscopic organisms to such animals as have been mentioned. With the shortening of the intestine the body itself shortens, so that the mature fish is often smaller than the immature form. Having become a Lamprey, it puts on a silvery appearance and moves into clear water. It is probable that having reached the perfect state it spawns but once. No other fish presents so remarkable a transformation.

Other species of the genus are found in British Columbia and in Buenos Ayres. One or two allied genera have a curious geographical distribution. The *Geotria chilensis*, a species about two feet long, which has a pair of long, pointed, lingual teeth, compared by Dr. Günther to the horns of a young Antelope, is found in New Zealand, the Swan River of Australia, and in Chili. The *Mordacia mordax* occurs in Chili and Tasmania, and has two pairs of serrated teeth on the tongue.

FAMILY II.—MYXINIDÆ.

The Myxinoids closely resemble the Lampreys in having a naked Eel-shaped body; the nostril similarly has a single aperture at the extremity of the head, but, unlike that of the Lampreys, the nasal

duct is not lined with cartilaginous rings in the manner of trachea. This duct opens by valvular apertures on the roof of the mouth. Sir Richard Owen, however, regards this organ rather as representing the spiracles of Sharks, which run from the top of the head to the sides of the branchial chamber. There are barbels on the head, the mouth has no lips, there is one tooth on the palate, and two teeth like small combs on the tongue. The branchial apertures are far removed from the head; mucous sacs extend all along each side of the abdomen. The intestine in these fishes, unlike that of the Lampreys, has no spiral valve. The eggs, too, are relatively large, and are contained in horny cases provided with short filaments, by which they become attached.

THE HAG.*

The vertebral column in this fish consists of soft substance, showing scarcely any trace of division into vertebral rings, the cartilage surrounding the semi-fluid primitive notochord. The usual length is about a foot; the body is compressed behind; the snout is conical, but rather blunt; the caudal fin reaches forward to the vent; its rays are numerous. There is another fin between the vent and the gill-openings which contains short stout rays. The lateral line contains more than a hundred glands, which form a bead-like chain along the body, and from these the mucus is poured out, which has suggested the specific name of the fish. Water enters by the nasal tube, so as to supply the gills, and in this respect cyclostomous fishes form an exception to the general law that the nostril has no respiratory function in fishes. The only other fishes in which the nostril opens on the palate are the Dipnoi.† At the back of the gullet in the Hag are six small tubes communicating with the sacs which replace the ordinary gills of fishes, and from these gills are passages which unite on each side into a single tube, opening on the belly, at about a third of the length of the animal from its mouth. The portal vein in this fish has a rhythmic contraction. The quantity of slime secreted from the body is prodigious. Couch mentions that a single individual placed in three or four cubic feet of water filled it so completely with the mucous secretion that the entire mass could be lifted out with a stick in a continuous sheet; and hence some of the older naturalists believed this fish had the power of converting water into glue. The eggs are large and yellow; no more than twelve have been found at one time in a developed state in the ovary. The ovary is placed below the notochord, and consists of plates. The fish is remarkably sluggish, but when it moves swims like an Eel. It frequents muddy ground, and lives in deep water. It is rarely captured, and never approaches the shore. It extends along the coasts of Europe and North America, but is chiefly known from northern waters. The mode in which this animal feeds is one of the most singular facts of natural history, since it enters by the natural apertures into the bodies of Mackerel and various fishes of the Cod family, and devours not only the intestines but often the flesh also. Sometimes the fisherman draws up on his line a Haddock, of which nothing remains but the bones and skin. This destruction is sometimes accomplished by a single Hag, but as many as twenty have been found in the body of a single fish. The Hag has occasionally been found partly digested in the stomach of a Cod. Another species is found in the temperate parts of the Pacific coast of South America.

The genus *Bdellostoma*, with a general resemblance to the Hag, has many branchial apertures on the sides of the body, each of which leads by a separate duct to a gill or branchial sac.

In the *Bdellostoma cirratum*, found at the Cape of Good Hope and New Zealand, there are six or seven of these gill-openings on each side, but in the *Bdellostoma polytrema*, from the coast of Chili, there are fourteen openings for the gills extending along each side of the abdomen. Thus in external appearance this fish presents some resemblance to the yet lower *Amphioxus*, which is the last and most degraded member of the fish class that is known.

* *Myxine glutinosa*.

† The following sentence was omitted from the account of the Mud-fish on p. 20, and should be added to the paragraph containing a statement of Sir Richard Owen's opinion:—"Subsequent researches, especially those of Professor Huxley, have demonstrated that the nasal sacs of *Lepidodiren* open on the inside of the upper lip, so as to form true posterior nares; but this correction does not affect the general truths of Owen's generalisation as to the closed nasal sac being a distinctive character of fishes."

DIVISION IV.—LEPTOCARDII * (FISHES WITH THIN HEARTS). ORDER PHARYNGOBRANCHII.

This concluding group of the fish class contains only two species—

FAMILY CIRROSTOMI.—THE LANCELET.†

This little fish is never more than three inches long, is transparent and iridescent, is very active, and has a fin extending from near the snout round the tail to the vent. The body is compressed, the head pointed; the eye is a dark speck in a slight depression of the skin; the mouth is an elongated oval, placed longitudinally and margined by slender filaments, which are ciliated and supported by a cartilaginous framework, which extends round the mouth. Behind the mouth is the pharynx, which is perforated by numerous vertical or slightly oblique branchial clefts, which extend far down the length of the body. Behind the pharynx is a simple stomach prolonged into a straight intestine, which terminates in a vent near the root of the tail. There is another aperture in front of the vent, which opens into a cavity distinct from the pharynx, which extends forward towards the mouth. The function of this pore appears to be to carry off the water, which, propelled inward to the pharynx by the mouth, passes through the branchial slits into the external cavity. In an early stage of development the branchial slits are entirely exposed on the sides of the body. There are no gills. The liver is an appendage to the intestine. The reproductive organs are glandular masses, arranged in a row along each wall of the body cavity. The heart has no trace of the muscular character seen in the higher Vertebrata, which have hence been distinguished from the Amphioxus as Pachycardii, while the name Leptocardii indicates the thin wall which is here seen in that organ. In fact, the heart is no more developed than is the heart of a chick when it first appears in the first few days of incubation. Contractions take place only at the rate of about one a minute. All the principal blood-vessels are contractile. The blood is quite colourless, and, as in the lower animals and the young of Vertebrata, the blood-corpuscles are nucleated, so that the red corpuscles have not as yet been formed. The skeleton is very imperfectly developed, and, beyond that part already referred to, around the mouth is limited to a notochord, which shows no trace of transverse division into vertebrae or of superior or inferior arches or ribs. It extends some distance in front of the spinal cord. There is therefore no skull or brain in any ordinary sense of the term, and the anterior extremity of the spinal cord, instead of enlarging, diminishes in size; it gives off nerves to the eye and the filaments round the oral region. The fish displays many analogies with the invertebrate group termed Ascidians, and somewhat resembles amphibians in the mode of formation of the cavity external to the branchial slits. The surface of the body is smooth and entirely destitute of scales. When first studied the Lancelet was mistaken for a slug, just as the Hag was mistaken for a worm. It has been kept in captivity, and observed to usually bury itself a little in the sand when disturbed. It is extremely sensitive to light; it often lies as though dead for half an hour or an hour together. This fish can scarcely claim to belong to the Vertebrata; it wants many of the more striking characteristics of fishes, and certain observers have sometimes surmised that it may possibly be an embryonic fish of which the mature form is unknown. This, however, is unlikely. But it differs from other fishes in characters in which they all agree, and differs also from fishes in points of structure which are common to them and higher Vertebrates. It might well form the type of a class standing alone, and helping by its low grade of organisation to indicate one of the lost steps of continuity between vertebrate and invertebrate animals. It frequents shallow water, and is widely distributed in temperate and tropical seas. A second species has been found in Moreton Bay.



LANCELET.

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FOSSIL FISHES.

A large proportion of fossil fishes belong to the division Paleichthyces. This group comprises most of the fishes which have been met with in the Primary rocks and many of those found in the

* *Leptos*, thin; *cardia*, heart.

† *Amphioxus lanceolatus*.

Secondary strata : but in Tertiary deposits the Teleostean division is quite as well represented in the geological formations as in existing seas. There is no evidence of any gradual succession of fishes in the order of increased complexity of structure, as the deposits in which they occur approach nearer to the present day. And there is no reason to suppose that the oldest fishes known were the first that appeared upon the earth. The earliest fishes discovered are met with in the lower Ludlow rocks, which form the upper part of the Silurian strata. The most ancient genus is *Scaphaspis*, a small buckler-headed fish, which had the body covered with scales. Many allied genera are found in the overlying Old Red Sandstone, in which fishes appear in extraordinary variety. Among the allies of *Scaphaspis* are *Pteraspis*, *Cephalaspis*, *Auchenaspis*, and *Didymaspis*, some of which range down to the Silurian rocks. Near to these fishes must be placed *Coccosteus*, *Pterichthys*, and the immense American fossil of Devonian age, named *Dinichthys*. These fishes are thought to be related to Ganoids and Sharks, but in external form they more closely approximated to *Loricaria*, though the tail is heterocercal. They form a distinct group named *Placodermi*. Existing fishes, however, with heterocercal tails, have the tail homocercal in an embryonic stage of development.

The Ludlow bone-bed consists almost entirely of bones of fishes much triturated and matted together, and very few species of fishes have been recognised in it, but among them is a Shark-like fish spine referred to the cestraciont genus *Onchus*. The more striking of the Old Red Sandstone fishes belong to the group which Professor Huxley names *Crossopterygidae*. This group of ganoids comprises many fossil families in addition to the living *Polypterus*. Among them are genera covered with rhomboidal scales, as in *Polypterus*, having two dorsal fins. The pectoral fins have the rays arranged round a long central scaly portion, so as to form a fringe. *Osteolepis*, *Diplopterus*, and *Megalichthys* are genera showing these characters. This tribe is named *Saurodipterini*. Another group, the *Glyptodipterini*, has sculptured scales, two dorsal fins, and the pectoral fins greatly elongated. Some of the genera, such as *Glyptopomus*, *Glyptolemus*, and *Gyroptichius*, have the scales rhomboidal ; but other genera, such as *Holoptychius*, *Glyptolepis*, *Platygnathus*, have the scales cycloid, and to this group probably belong *Rhizodus*, *Dendrodus*, and other types. Another section formed for the genus *Dipterus* is termed *Ctenodipterini*. All its fins are elongated, and look like lobes of the body. Its scales are cycloid, and the teeth are crossed by ridges. The genus *Phaneropleuron* has one long undivided dorsal fin and thin cycloid scales : its teeth are conical. The *Celacanthini* is another remarkable group of these fishes, which have the air-bladder large and ossified. It includes such forms as the *Celacanthus* and *Macropoma*, which latter ranges through the Kimmeridge Clay to the Chalk. A section of the Ganoid order, represented at the present day by *Lepidosteus*, appears in the Secondary strata to have attained an immense development ; but while the living *Lepidosteus* has the maxillary bone divided into several pieces, the fossil genera of the Lias and other Secondary formations have the maxillary bone in one piece. Among the better-known fossil genera are such types as *Lepidotus*, *Dapedius*, *Tetragonolepis*, *Eugnathus*, *Pachycormus*, and *Aspidorhynchus*. The fishes allied to *Pycnodus* have the jaws covered with rows of flat-crowned teeth, adapted for crushing, with sharp incisor teeth in front. *Pycnodus* ranges through the Secondary rocks up to the Tertiary, a species being found in the London Clay of the Isle of Sheppey. Closely allied to these forms are genera from the Primary rocks, such as *Platysomus*, in which, as in the *Paleoniscidae*, the vertebral axis is notochordal, the caudal fin is heterocercal, and the scales have the ganoid character. The fishes resembling *Platysomus* have a short and deep body, which is more or less ovate and rhomboidal in outline, while genera allied to *Paleoniscus* have the body much more elongated. The *Acanthodini* are fishes with small scales like shagreen. Each fin carries a strong bony spine in front. *Chiracanthus* and *Acanthodes* have a single dorsal fin, but *Diplacanthus* has two dorsal fins. These genera are chiefly found in the Old Red Sandstone. The Dipnoal fishes are represented in a fossil state by the Devonian genus *Ctenodus*, and *Ceratodus*, known from teeth in the Trias and lower Oolites. The Chimæroid order does not range further back in time than the Lias. It is represented by species of *Ischyodus* and *Edaphodon* in Secondary strata, and by the genus *Elasmodus*, which is only known from Tertiary deposits. Fossil Sturgeons from the Lias belong to the genus *Chondrosteus* ; in the London Clay the *Acipenser toliapicus* is found. Of Sharks, the strata yield many remains, but they are chiefly known from teeth and the defences which support the fins. The slug-like teeth of *Acrodus*, *Strophodus*, and *Ptychodus*, in the Secondary

strata, are allied to the Cestracion, as are the teeth of *Psammodus*, *Petalodus*, and other genera found in the Carboniferous rocks. The grey Sharks are represented by species of *Notidanus* in both the Cretaceous and Tertiary rocks. The Porbeagle genus *Lamna* has many species in the same formations. The Skates are well known in a fossil state. A large number of the doubly-serrated spines, found in the Coal Measures, appear to belong to the Trygonidae. Other types, like the Eagle Ray, are well represented by such genera as *Zygobatis* and *Myliobatis*. Fossil species of *Torpedo* are met with in the Tertiary deposit at Monte Bolca. Saw-fishes exist in the lower Tertiaries of the London and Hampshire basin.

The Teleostean fishes chiefly belong to the larger orders. Although the Teleostean fishes in an embryonic stage have the tail heterocercal, and afterwards grow through that into the homocercal stage, the fossils hitherto found afford no demonstration that Teleostean fishes have been evolved from the Paaleichthyes. The Perch family is well represented in a fossil state, especially in the Tertiary formations of Monte Bolca and Eningen. The Sea Breems date back to the Cretaceous rocks of Mount Lebanon, and the family is well represented in the Lower Tertiary strata. The Scorpenidae, a family remarkable for often possessing poison glands on the spines, is represented by a fossil species of *Scorpena* from the Eocene of Algeria. Fishes allied to *Beryx* are known from the Cretaceous and Tertiary rocks of many parts of the world. The Sword-fishes first appear in the Chalk of England. An extinct genus of this group is found in the London Clay. The family Trichiuridae are well represented in the Secondary rocks, especially the Upper Greensand and Chalk, by the genus *Enchodus*, which has long strong teeth. In the Tertiary beds this family becomes more abundant, while several existing genera occur in the newer Tertiary strata. Closely resembling these fishes is the extinct genus *Palæorhynchus*, which has jaws forming a long beak; it is found in the slates of Glaris. The family Acronuridae is represented in the deposits at Monte Bolca by fossil species of the living genera *Acanthurus* and *Naseus*. The carnivorous family Carangidae date back to the Secondary period. The family Coryphenidae have some Tertiary representatives chiefly from the Isle of Sheppey and Monte Bolca. The Mackerel family have only been found in the fossil state in Tertiary beds. Fishes allied to the Star-gazer have been met with in the newer Tertiary formations. The Gurnards are known from species of *Trigla* and a few other genera in beds of Tertiary age. Closely allied to the Flying Gurnards is the genus *Petalopteryx*, from the Chalk of Mount Lebanon. The Gobies are found for the first time in the Chalk, but extinct species of *Gobius* occur in the older Tertiaries. The family Sphyrenidae are well known by such genera as *Hypsodon* and *Portheus*, in the Chalk, while various other genera represent the group in Tertiary deposits. The Grey Mullet first appear in the Tertiaries of France. The Wrasses are represented in Tertiary rocks by the genus *Egertonia* from the London Clay of Sheppey, and by species of *Labrus* and other genera in the Lower and Middle Tertiaries of Switzerland. The fossil remains of *Anacanthini* are not abundant. Fishes allied to the Cod and Hake are found in the London Clay; other members of this group are found in newer Tertiary deposits. Flat-fishes, allied to the Turbot and Sole, occur at Monte Bolca. The order Physostomi has many fossil representatives. The family Scopelidae are, perhaps, represented by *Osmeroides* in the Chalk and by other genera in the Tertiaries. The Carps do not date farther back than the middle Tertiary deposits, being plentifully met with in the lignites of Germany. The Cyprinodontidae are represented by species of the genus *Cyprinodon* in deposits of the same age. Fossil Pike are found in the fresh-water limestone of Eningen. The Salmon tribe is represented by several genera in the Chalk. The Herrings are numerous in the upper Secondary rocks, though more abundant in the Tertiaries. And the Eels first appear in the older Tertiary formations. The Pipe-fishes do not appear before the Tertiary period, and in the same formation at Monte Bolca the Box-fish Ostracion occurs. Glyptocephalus, from the London Clay, is allied to the File-fish *Balistes*. Globe-fishes allied to *Diodon* are found fossil at Monte Bolca. Forms intermediate between Eels and Congers occur in the London Clay. The Lampreys have no parts likely to be preserved in a fossil state, unless some of the fossils called *Conodonts*, from the Primary rocks, are teeth belonging to this group.

In writing this article I have to acknowledge the obligations I am under to the various works of Dr. Günther, Yarrell, Couch, and Sir Richard Owen.

H. G. SEELEY.

THE ANIMALS WITHOUT BACKBONES—THE INVERTEBRATA.

INTRODUCTION.

Characteristics of Vertebrata—Modifications—Characteristics of the Invertebrata—Various Distinctions among Themselves—Habits—Classification—Intermediate Groups.

THE animals, whether mammals, birds, reptiles, amphibians, or fish which have been described or noticed hitherto in this work, have some parts of their construction which are similarly placed, and fashioned after one plan. They have a series of bones, or vertebrae, forming the spinal column, upon which the skull is placed; and these structures separate the brain and its continuation—the spinal cord—from the organs of digestion and respiration, and from the main organs of circulation.

These animals constitute the great group of the animal kingdom, which is called the "Vertebrata." They have red blood, and in some classes it is warm, and in the reptiles, amphibians, and fish it is cold. They have an internal skeleton, and never more than two pairs of limbs, and these are modified to meet the wants of the different classes, and in some instances they are more or less defective. One side of the body has a general resemblance to the other, but different organs are found on opposite sides within, in relation to the digestion and circulation, so that there is, generally speaking, a bilateral symmetry. The development of the nervous system, and especially of the spinal cord, brain and large nerves, is considerable even in the fish, and is increasingly great in the amphibians, reptiles, birds, and mammals. The organs of special sense—seeing, hearing, smelling, and of the sense of touch—are highly developed for the most part, and their possessors lead, sooner or later, independent lives, and seek their food.

Taking the great Apes as the highest of the animals we have noticed, and the *Amphioxus* as the lowest, so far as the scale of construction is considered, they and the intermediate mammals, birds, reptiles, amphibians, and fish are linked together by possessing many similarly arranged structures. The mammals can be readily distinguished, but the simplest and lowest of them, the *Monotremes*, have many points of anatomical resemblance with the reptilia and birds. The birds are linked on to the reptilia of the past history of the globe, and the reptilia to the amphibia and fish. Moreover, these last are closely allied by kinds which have structural arrangements that can hardly be definitely said to be those of the amphibian or those of a fish. From the history of the past, it is gleaned that these great groups, so interestingly linked together in the chain of natural classification, began to be and appeared in the order of their present classificatory position. The fish and amphibia preceded the reptilia; birds came next, and then the lowest kind of mammal. Thus, by their possessing an internal skeleton, a backbone, a skull, and limb-bones; by their having the nervous and vegetative systems separated, the one near the back (*dorsal*) and the other ventral; by their classes being connected by many common structures and by their geological history, the Vertebrata are a remarkably distinct and recognisable group.

These general statements have only to be modified in a few instances. In some of the simplest Vertebrata, that is to say, in some whose construction is less elaborate than in others, the spinal column, with its succession of separate bones, is replaced by an elongated rod of cartilage which is flexible, and to which certain membranes adhere. One membrane is folded above the rod (in the swimming position of the fish *Amphioxus*, page 147), and envelops the spinal marrow, and two others extend in the opposite direction and form and bound the cavity which contains the viscera. This rod, or *corda dorsalis*, really supports the spinal nervous system, and separates, as in the other Vertebrata, the nervous and vegetative organs. It exists in the early unborn or embryonic state of all animals which have, when born, a series of jointed vertebrae forming a backbone, and it is probable that the first fish that lived on the globe had this *corda dorsalis* or notochord only.

In the *Amphioxus* there is no true brain-case, and the special senses of hearing and seeing are at their lowest ebb, the ear being deficient, and the single eye is a mere mass of pigment, placed on the nervous swelling at the fore part of the spinal marrow which represents the brain of other Vertebrates. There is, therefore, no brain in this creature, and were it not for the cartilaginous rod and the relative position of the nervous system and of the digestive and circulatory organs—the one above and the other below the rod—the animal could hardly be called one of the Vertebrata. It has colourless blood, it has no true jaws, and the mouth opens into a cavity which is used for the

purposes of digestion and of respiration. The heart proper does not exist, but there are large blood-vessels which are contractile and move the blood. It is the simplest animal amongst the Vertebrata.

All the animals which are about to be described are *invertebrata*, that is to say, they have no jointed, bony, or cartilaginous spinal column, with a brain-case, and limbs, whose bones are connected with the internal skeleton. Even the cartilaginous rod or notochord is not found in any of the adults. This absence of the support and case of the great nervous centres is the great distinction between the animals which may be roughly exemplified by the Cuttle-fish, the Oyster, the Ascidian, the Insect, the Worm, the Starfish, the Coral, and the Amœba; and the Beasts, Birds, Reptiles, Amphibians, and Fishes. It is a negative distinction, but it is, nevertheless, pregnant with interest, for it seems to establish one of the few great breaks in the continuity of nature. So far as adult and fully-grown forms are concerned, the break is perfect. But were the imperfect young (the embryos) of one group of the Invertebrata—the Tunicata—to be considered especially, it would be found that they have what may be called the rudiments of a notochord, but placed far back, however, in relation to a tail, and not having the relative position to the nervous system and vegetative organs which is noticed in the Vertebrata. It is also true that there is a great similarity between the minute structures of some Invertebrata and those of the higher animals.

The Invertebrata present almost every variety of shape. Some are without any definite form, and change their shape constantly; others have no distinct head; many have the body arranged in joints or segments, and one side of their body resembles the other, and their symmetry is then said to be bilateral. A great group have their structures arranged in a radiate manner like the Starfish, and many others have their head distinguishable from the body. Although no internal skeleton exists with its limbs, after the fashion of the Vertebrata, yet the body may have particles of carbonate of lime or silica here and there in it, and often arranged in beautiful geometric patterns: or a test or shell may cover part or the whole body, or be included within it as a kind of support. In many great groups an external armour of shell or of hard skin is perfect and very elaborate in its varieties of shape and ornamentation. Many have soft skins. Their methods of locomotion are sometimes in relation with the external hard structures, which consist of skin or dermal structures, more or less modified, and provided with mineral matter or a substance called chitine, but this is not always the case. Some move on the ground with a slimy kind of foot, like the snail and slug; the one is provided with a complete shell into which it can withdraw, and the other has but a small hard portion. Others crawl under stones, make their way in the earth, and move over the surface like worms, and have either a hard coat to their segments, or a perfectly soft and slimy one. Those which lead the life of the insect may have hard or soft bodies at some period of their lives, and may be provided with limbs of more than two pairs in number. In some the development of legs and limbs is so great that nearly every segment of the body has them on opposite sides, and the piercing, sucking, capturing, and masticating organs are really modified limbs, and are not like the jaws of the Vertebrata. Some move by articulated limbs like the Crab and the Beetle, others have a coronet of long fleshy tentacles covered with suckers around the head; wings may exist as in the Butterfly, and correspondingly useful expansions exist around the neck of the swimming Pteropods. But these have no internal skeleton, and the limbs, &c., are essentially skin structures.

A vast number of the Invertebrata have the body covered with minute and rapidly vibrating structures, visible only under the microscope, called cilia; some are long and others are short, and they move the body in the water with great velocity. Again, some groups of this great division are without these remarkable simple structures. There are members of this lower group of the animal kingdom which move by taking in water and ejecting it in an opposite direction as they swim in the water; and not a few live in the water, fresh or salt at one, and in the air at another, period of their lives, or air and water are a common home; many live on the surface, and others on the floor of the deep sea. A great number of kinds lead an independent and moving life in their early days, and then fix on to some substance, or on another and larger animal, and remain sedentary, and some of them are then absolutely fixed like the reef-building Corals and the Barnacles; some may be fixed or remain still by their weight like the Oyster, and others anchor by a set of threads like the Mussel. On the other hand, some kinds, such as the Jelly-fish, are free movers in the water at first, then they settle down and become fixed and grow unlike their parent, and finally develop young, which, as they

grow and lead a free life, return to the parental shape. In the caterpillar, which lives to eat, the chrysalis, which is stationary and quiescent, and the free-flying moth, which may never touch food, the metamorphosis is very complicated; in others it does not occur at all, the young being born the image of their parent. Now, in all these instances the covering differs at different periods of their life, and moulting of it is frequent. Beautiful hairs, scales, and other modifications of the skin occur, and the colour is often striking and changeable. On the other hand, a colourless body may exist furnished with slime cells. Again, in some of the groups the skin is modified into stinging organs, as in the Jelly-fish and Coral. Muscles are attached within to these outside structures, which are thus of as great importance to the Invertebrata as the skeleton is to the Vertebrata.

The breathing, whether in air, fresh or salt water, takes place by the action of the whole, or part of the whole skin, by parts of it which are arranged and ciliated like gills, or which are turned inwards, like sacs and tubes within the body. Either the process is simple, the air or the aerated water coming in inevitable contact with the skin and its modifications, or, as in the Insecta, the movements of the segments of the body expel and draw in air. The circulation is carried out by contractile vessels in the higher groups, but none of them have the simplest vertebrate heart, although that of *Amphioxus* is initiated to a certain extent. In some the current of blood can be reversed. A great number have no organs of circulation, the juices pouring from part to part in an almost plant-like manner. The colourless blood is often without any corpuscles. A system of water channels and spaces often exists. The nervous system may be greatly concentrated in the head, and it then is situated above and below the gullet, there being branches on either side. A long cord with swellings, or ganglia, passes from the brain along the inside of the lower or ventral side of the body in a vast number of genera. In others the nervous system is supplied to the principal organs and foot in an unsymmetrical and irregular manner, and in the lower groups, whose construction is simple, the nervous element is extremely difficult of demonstration, and may radiate from centres, pass round the body, giving off threads to special organs, or may merge here and there into muscular structures, there being nothing like a nervous centre. No structure comparable with voluntary nerve fibre within is visible in the simplest forms of the Invertebrata.

Some of the Invertebrata have organs of special sense faintly developed, in comparison with those of the Vertebrata. Simple and compound eyes, or mere spots of pigment in contact with nerve, are common, but many groups are without any special structures by which light can be distinguished, although the influence of it is evident enough on their bodies. In one group the eye is internal and useless during a part of their life. Rudimentary but most useful organs of hearing exist in some; tactile nerve is exceedingly delicate in many; and a knowledge of the presence of food, or of substances, which give an impression of disgust to man, is evident enough in so many kinds, that something analogous to the sense of smelling must be present in them.

Many Invertebrata exist in very cold water, others live in warm brine springs, some require the purest air or the purest water, whilst not a few—which are parasites—live in impure situations. The intelligence and constructive acts of many Invertebrata are as evident as the simple, mechanical, and automatic lives of others; and it does not appear that it is possible to connect the highest intelligence with the highest development of the body generally in any scheme of classification. Moreover, the kind of intelligence differs in the different phases of the lives of many of the Invertebrata. There are many instances in which care is taken of the young by the parent or by the community, but in the majority this is not the case.

The methods by which the Invertebrata increase and multiply are numerous and extraordinary. Spontaneous division of the body, in one or more pieces, each becoming a separate animal; separation of the tissue of the whole creature into a vast number of minute microscopic globules, which burst forth and grow into the parent shape; separation of little pieces from the outside or inside, these becoming independent; a process resembling internal budding; the formation of living young within the body, which pass forth not in the egg, but resembling the parent; and the laying of eggs, are the commonest. But the results of the egg-laying are as extraordinary as the other methods. Some eggs are produced by virgin mothers, and in the hatching of all eggs there is a process of evolution within the egg envelope or shell. Most young thus produced do not resemble the matured parent, and pass through different stages of existence and shape before attaining maturity; and whilst

some advance in complexity of structure, others positively retrograde. A great number of kinds of several groups of the Invertebrata live the lives of parasites on or within other animals, and the great differences in shape and gifts which are noticed in the life cycle of these creatures are in relation to this fact. Some positively exist on the juices of their unwilling host, others are so placed that they help themselves to the food of their fellow-feeder, or to the supply set apart for its offspring.

The great division of the Animal Kingdom whose members have these characters cannot be classified as simply as the Vertebrata. The range of structural peculiarities is vast from the shapeless microscopic entity, which can only be separated arbitrarily from the lowest and simplest plant to the great Cuttle-fish. It does not appear possible to arrange the groups of the division in an ascending series by the nature of their nervous and other structural developments or intelligence, but several are on a level, as it were. Again, the history of the past does not assist us in explaining the succession of the Invertebrata on the globe, for in the oldest rocks, which afford evidence of a satisfactory nature, the highest amongst the Invertebrata are represented.

The classification, which is as natural as is possible under the circumstances of existing knowledge, but which, nevertheless, is very artificial, is as follows:—

The Invertebrata are divided into great types, or groups.

1. *The Mollusca*.—These are animals with a soft body, without segments, naked or covered with a shell of one or two valves composed of carbonate of lime, secreted by a fold of the skin—the mantle. They have a brain mass, and foot and mantle ganglia. Some have an internal hard shell, or cartilage. The symmetry of the body is bilateral. Example, Cuttle-fish.

2. *The Arthropoda*.—The body is in ringed segments of various shapes, provided with limbs; the brain is united to a ganglionic cord, which passes along the ventral surface within. The symmetry is bilateral. Example, the Common Fly.

3. *The Vermes*.—The body is either without segments, or may be composed of nearly similar segments, without articulated limbs. The symmetry is bilateral. Example, the Earth-worm.

4. *The Echinodermata*.—The body, or part of it, is arranged in a radial manner, the divisions being generally five in number. The skin contains or is covered by a symmetrical armour of plates of carbonate of lime. The digestive and circulatory organs are distinct and separate. There is a nervous system, and locomotion proceeds by ambulant tentacles. Example, the Sea Urchin.

5. *The Zoophyta*.—The body is arranged in a radial manner in divisions of four or six, or their multiples. A visceral cavity serves for digestion and circulation. Examples, the Coral and the Jelly-fish.

6. *Protozoa*.—Minute animals, with very simple organisation; structures, slightly differentiated; often unicellular. Examples, Animalcules and Sponges.

These great divisions are not exactly defined in nature, and they are subdivided into secondary groups, and are also united in some instances by forms of life which cannot well be placed in any particular one.

INTERMEDIATE GROUPS.

1. *The Tunicata* have a more or less leathery or cartilaginous covering sac, which is more or less tub-shaped; a gullet with perforations leading to a respiratory cavity, surrounded by an inner skin, which envelops the viscera also. There is a simple nervous ganglion placed dorsally, and a rudimentary heart. The symmetry is to a certain extent bilateral. They may be placed in the neighbourhood of the Vermes and Mollusca in their classification. Example, the Ascidian.

2. *The Molluscoida* have the body with shells placed differently to those of the Mollusca, or have a tubular or shell-like covering. The gills are more or less free and fringed with cilia, without the usual lamellæ of the Mollusca, and they serve the process of the capture of food as well as of respiration, or there may be a crown of ciliated tentacles. *The Bryozoa and the Lampshells, or Brachiopoda*, are included in this group, and in their structures, embryonic and adult, they show resemblance to those of Vermes, Mollusca, and Tunicata.

These types or great groups are subdivided into classes, orders, families, genera, and species, which will be indicated in the description of their natural history.—EDITOR.

INVERTEBRATA.—TYPE MOLLUSCA.

CHAPTER I.

THE CEPHALOPODA.

Cephalopoda—Derivation of the Term—Unexpected Relationships—Shells—Utility of Aquaria—General Characters of the "Naked" Cephalopods—Classification: the Dibranchiata and Tetrabranchiata—Their Mode of Locomotion—The Mouth and Eyes—Means of Escape and Defence—Representative Dibranchiata in the Ancient World—DIBRANCHIATA, OCTOPODA—ARGONAUTIDÆ—The Argonaut, or Paper Nautilus—Its Fabled Position—Its Praises as Sung by the Poets—How the Nautilus really Swims—The True Uses of the Arms—Curious Fact regarding the Shell—The Male as Compared with the Female—The "Hectocotylus"—Species of Argonaut—OCTOPODIDÆ—The Common Octopus—Appearance—Formidable Seizing Organs—Owen's Description of the Tentacles—Mechanism of the Suckers—The Octopods of Leghorn—The Octopus of the Greeks—Mr. Darwin's Account of the Octopus—A Diver Attacked—The Adventures of an Octopus in an Aquarium—Spawning Season—Eggs of the Octopus—Henry Lee's Observations as to the Hatching of the Eggs—The Baby Octopus—New Growth of Amputated Limbs—Food for Predatory Fishes—Contests with the Conger Eel—The "Devil-fish" and Nursehound—Various Species of Octopus—De Montfort's Gigantic Octopus—Cuttles and Octopus as Diet—Octopus Fishery—DECAPODA—TEUTHIDÆ—Distinctive Features—The Tentacles—Suckers—Shell—Remarkable Skin Characters—Play of Colours—THE COMMON SQUID—"Pen-and-ink Fish"—Their Spawn—The "Little Squids"—The Nerve-masses of the Dibranchiata—A Tom Thumb Cephalopod—*Lolipais*—*Cheiroteuthis histioeuthis*—The Clawed Calamary—Construction of the Suckers of the Calamary—The Armed Calamary—The Sagittated Calamary—"Sea-arrows"—Squid-bait—The Cod-fishery—Squid-jigging—The Giant Cephalopods—Instances of their being Met with, and of their Capture—Sir Francis Chantrey and Fossil Ink—BELEMNITIDÆ—No Living Representative—What the Fossil really is—Species—SEPIADÆ—The Common Cuttlefish—Beautiful Coloration—The Bone or Shell—The Cranial Cartilage in the Cuttle—The Heart—Movements in the Water—Not Long-lived in Confinement, and why—The Cuttle's Eye—The "Ink-bag"—Discharge of the Ink—Use of the Ink—The Eggs of the Cuttle—Young Cuttles—Uses of the "Bone"—Various Species of Sepia—The Cuttle as an Article of Diet—SPIRULIDÆ—Genus *Spirula*—Remarkable Characters—Rarity—Difficulty of Studying it—Peculiar Shell Characters—ORDER TETRABRANCHIATA—NAUTILADÆ—External-shelled Cephalopods—Nautilus and *Spirula* the only Siphonated Shells Living—Construction of the Shell—Rumphius's Account of the Pearly Nautilus—Mr. Moseley's Observations—How the Animal Moves—Abundance—Various Parts of the Nautilus—The Air-chambers—The Uses of the Siphuncle—Formation of the Septa—Fossil Members of the Tetrabranchiata.

CLASS I.—CEPHALOPODA.

ONE of the foremost groups in the Molluscan division or type of the Invertebrata is that of the class Cephalopoda*, so called by Cuvier, because the animals included in it have their feet or tentacles attached to the head, around the mouth, a simple and convenient arrangement for taking in food, which we shall presently find repeated in some other groups, such as the Stone Lilies and Sea Anemones, &c., nutrition being the highest ambition of the lives of at least a large majority of these animals.

The Octopus, or "devil-fish," the Cuttle-fish, and the Pearly Nautilus are excellent examples of these head-footed Mollusca, which (like the Sharks among existing fishes) represent at once a very ancient and singular group, but are nevertheless true Mollusca. The Garden Snail does not appear, on a cursory inspection, to have much in common with the "Sea Squid," or the "Cuttle-fish," but the Garden Snail is first cousin to the Slug, which has no visible shell, and the shell-less Octopus is next-of-kin to the Pearly Nautilus, which carries its shell upon its back.

Thanks to our public museums, we have long been familiar with those beautiful objects, *Shells*; and every schoolboy knows the look of the commoner forms of living Mollusca, such as Snails, Whelks, Mussels, Oysters, and Cockles, but it is only within the last few years that the introduction of Marine Aquaria in many of our large cities has made us really acquainted with sea-shells and their inhabitants in a living state. To these establishments we are more especially indebted for a knowledge of such forms as the Cuttle-fish and Octopus and their relatives, seldom seen upon our sea-shores, of which we have first to speak.

By far the larger part of the existing members of this great division of the Mollusca, or soft-bodied animals, are unrepresented in museums or cabinets of shells, either because, like the Octopus, they have no shell, or, like the Squids, Calamaries, and Cuttles, they have only an internal one, which is often very delicate and not easily preserved. But this is not the case with all the Cephalopoda; for the Pearly Nautilus has as solid and compact a shell as any to be found among the whole Molluscan group, and so had the old fossil forms of Nautilus and Ammonite, of Goniatite and Orthoceras, whose chambered shells are to be met with preserved as fossils in rocks of very different ages and countries all over the globe.

* From *kephale*, Gr, a head, and *pous*, Gr., a foot.

This leads to the consideration of the class characters by which such varied forms of shell-bearing and shell-less animals can be known and recognised when found. Unlike those of some Mollusca, the organs of the Cephalopoda are symmetrically arranged, having their right and left side equally developed. The shells, too, of those forms which possess such an external covering, also grow symmetrically. But only two among all the existing representatives have any external shells, namely, the Nautilus and the Argonaut, all the rest are termed "naked" Cephalopoda, because they have only an internal shell entirely hidden within the soft parts of the animal's body. They have a distinct head, upon which, and around the mouth, are placed the principal appendages of the body in the form of a circle of muscular arms or tentacles. These members fulfil the office alike of seizing and holding the prey, and also act as organs of locomotion; hence the name "head-footed" given to the class. The free-swimmers, such as the Squids, Calamaries, and Cuttle-fishes have fins, which aid them in progression through the water, but all rapid movement is effected by the forcible expulsion of the water through the funnel from the respiratory chamber. Their progress, indeed, is effected stern-foremost, as in the case of a rocket, the backward discharge in both instances being the cause of their onward progress.

The typical forms of the Cuttle-fishes were known and described by Aristotle more than 300 years B.C., but it remained for Professor Owen to point out the existence of two distinct and separate orders of Cephalopods, clearly characterised by their respiratory organs, and to demonstrate how inseparably this organisation was connected with the condition of the two types, the free-swimming Cuttle-fishes on the one hand, and the sluggishly-crawling Nautilus on the other.

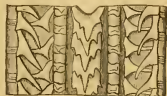
Among the great groups of animals already described, various leading modifications of structure were specially noticed, by seizing on which naturalists have been enabled to classify them readily; so also in the Cephalopoda, one group—representing the Squids, Cuttles, Calamaries, the Argonaut, and the Octopus—were found to lead very active lives, and to be excellent swimmers, and as they had only two gills, Professor Owen called them "Dibranchiata." The other group—limited nowadays to the Pearly Nautilus, but formerly, as will be seen anon, quite a dominant class in the seas and oceans of former ages—Professor Owen found to possess four gills, and named them "Tetrabranchiata." They were rather sluggish in their habits, as compared with their modern classmates, proving clearly that habit and function are directly co-ordinate with one another.

All the Cephalopoda are marine and carnivorous, and possess considerable locomotive power. At the bottom of the sea they can walk about head downwards, by means of the tentacles which surround the mouth, and which are usually provided with numerous suckers or "acetabula."* They are also able to swim, partly by the aid of lateral expansions of the integument or by fins, but chiefly, as has been already stated, by the forcible expulsion of water through the tubular ex-current funnel from the respiratory chamber, in which the two or four plume-like gills are placed.

The mouth is armed with powerful jaws, resembling in form, texture, and position the mandibles of a bird, being especially like a parrot's beak in shape. The tongue is large and fleshy, and, in part, seems to be endowed with the organs both of touch and taste, and, in part, it is armed—as in the Garden Snail, and the Rock Limpet, and other Gasteropods—with recurved spines or teeth.

But the eyes are perhaps the most striking organs in these creatures, being both large and brilliant, and well express the keen activity and alertness for which the majority of this wonderful group are conspicuous.

It has already been noticed that nearly all the existing forms of Cephalopoda belong to the naked-bodied, or internal-shelled, section—the two-gilled (or Dibranchiata). Members of this division cannot rely upon the protective covering of their shells as the Garden Snail does, but like the Garden Slugs, many of which, we shall presently see, have small rudimentary internal shells, they have to rely on cunning, or greater activity, and the substitution of other means of escape and defence, than those which a strong external shell would have afforded. They possess powerful tentacles, furnished with suckers,



TONGUE OF THE OCTOPUS.

* *Acetabulum* (pl. *acetabula*), Lat., a cup, a calyx: a term applied to the suckers or "cups" on the arms of the Cuttle-fish and other Dibranchiate Cephalopods, which have been hence termed *Acetabulifera*.

more perfect organs of vision, and they are able to secrete an inky fluid with which to cloud the water, and so conceal their retreat.

The Dibranchiate order of Cephalopoda also had its representatives in the seas of the ancient world, as the shells called *Belemnites*, or "thunder-bolts," the fossil shells of *Sepia* discovered by Cuvier, and the horny rings of the acetabula or suckers, found by Buckland in the fossil exuvie of *Ichthyosaurus*, sufficiently testify; but our knowledge of this order is chiefly founded on observation of existing species. These are extremely numerous; they frequent the seas of every clime, from the ice-bound shores of Boothia Felix to the open main, and floating "gulf-weed," or Sargasso Sea, of the equator Atlantic; they seem, however, to be most abundant in temperate latitudes. Many species frequent the coasts, creeping among the rocks and stones at the bottom; others are pelagic, swimming well, and are found in the open ocean at a great distance from any land.

ORDER I.—DIBRANCHIATA. SECTION A.—OCTOPODA.

FAMILY I.—ARGONAUTIDÆ.

The first section of the Dibranchiate order are called Octopoda, from the fact of their possessing only eight arms furnished with suckers. In it are placed two apparently very dissimilar families, the Argonaut, or Paper Nautilus, and the Octopus, or Devil-fish.

The Argonaut is perhaps the most interesting of this group, from the legends connected with its sailing propensities. It is the only member of the Dibranchiate order which secretes an external shell. But the shell is developed only by the female, the male being destitute of any calcareous covering. It was the *Nautilus (primus)* of Aristotle, who described it as floating on the surface of the sea, in fine weather, and holding out its sail-shaped arms to the breeze, a pretty fable, which poets have repeated ever since. Thus the Argonaut, or Paper Nautilus, has been regarded as giving to man the first lesson in the art of navigation. It has been usually represented with six arms extended over the sides of its little vessel to act as oars, and two others upraised as sails. Such having been the universal belief among the earlier naturalists, it is to be expected that poets would not fail to celebrate its nautical powers:—

"The tender Nautilus who steers his prow,
The sea-born sailor of his shell canoe,
The ocean Mab, the fairy of the sea,
Seems far less fragile, and, alas! more free.

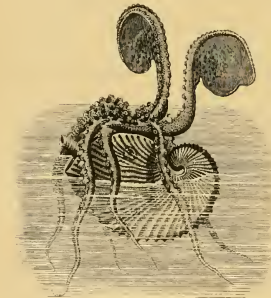
He, when the lightning-wing'd tornadoes sweep
The surge, is safe—his port is in the deep—
And triumphs o'er the armadas of mankind,
Which shake the world, yet crumble in the wind."—
BYRON.

Again, Pope bids us:—

"Learn of the little Nautilus to sail,
Spread the thin oar, and catch the driving gale."

And James Montgomery, in his "Pelican Island," gives a picture so exquisitely finished that even the naturalist can scarcely bring himself to wish that it were different:—

"Light as a flake of foam upon the wind,
Keel upward from the deep emerged a shell,
Shaped like the moon ere half her horn is fill'd;
Fraught with young life, it righted as it rose,
And moved at will along the yielding water.
The native pilot of this little bark
Put out a tier of oars on either side,
Spread to the wafting breeze a twofold sail,
And mounted up and glided down the billow
In happy freedom, pleased to feel the air,
And wander in the luxury of light."



FABLED POSITION OF THE PAPER NAUTILUS.

It is now ascertained that the Nautilus never moves in the manner here described. The account, though so universally accredited, is altogether fabulous. It swims backwards by ejecting water from its funnel, like other Cuttle-fishes. It can creep along the bottom, carrying its shell over its back like a snail,



PAPER NAUTILUS AND OCTOPUS.

and like many other molluses, it can rise to the surface; but there the arms are never employed as oars: and those which have the broad expanded membranous disc are never used as sails. Their true function, as ascertained by M. Rang, and confirmed by the experiments of Madame Power, is the secretion of the substance of the shell. They are stretched tensely over its surface, and, when accidental injuries arise, they deposit for its repair the needful quantity of shelly matter. To do this, and to supply what is wanted for the enlargement of the shell with the growth of the animal, is their appointed duty, precisely similar to that of the mantle in Sea Snails and bivalve shells.

We have spoken of the shell of the Argonaut as an "external shell," but this is true so far only as regards the fact (unique in the molluscan class) that the animal is not actually attached, organically, in any way to its shell. But the shell itself is so completely enveloped and held fast by the expanded lobes of the dorsal shell-secreting arms, that it may, without incorrectness, be called an "internal shell," its delicate, almost paper-like substance, proving its entire unfitness for a protective covering if exposed to the action of the sea.



ARGONAUT AS IT SWIMS BACKWARD (NATURAL POSITION).

As before remarked, the female Argonaut alone secretes a shell, which serves as the cradle or receptacle for the attachment of her eggs. The male, which is very much smaller than the female,

is naked, and looks like a little Octopus with short, pointed arms. The third arm, on the left side in the male, is specially modified, and is said to be "hectocotylised," being in some instances entirely detached, thus forming, as it were, a distinct organism, with independent locomotory powers of its own. The "hectocotylus" of the Argonaut resembles a little worm, with two rows of suckers along its length, a long filiform appendage at one extremity, and a small swelling at the other. When first discovered it was regarded as a parasite, and termed *Trichoccephalus acetabularis* by Delle Chiaje, while the corresponding body, found in an Octopus, was called *Hectocotylus*



PAPER NAUTILUS IN ITS SHELL.

octopodis by Cuvier. At first it has the form of a sac, within which the slender terminal part of the arm is coiled up. The sac then splits to give exit to the hectocotylus, and its two halves reunite on the outer face of the base of the arm, forming a chamber for the reception of the spermatophores. These are either placed within the mantle-cavity or fixed to the internal surface of the buccal cavity of the female. The hectocotylus is in fact only an arm irregularly metamorphosed and spontaneously detached.

Four species of Argonaut are known; these all inhabit the open sea, and have been met with throughout the warmer parts of the globe. Captain King records the capture of a Dolphin six hundred leagues from any land, from the stomach of which several Argonauts were taken.

The delicate paper-like shell of one species of Argonaut (the *A. hians*) has actually been met with in a fossil state in the Tertiary deposits of Piedmont. The same species is now found living in the China seas.

FAMILY II.—OCTOPODIDÆ.

The members of this family have only an internal rudimentary, uncalcified shell, represented by two short styles or plates, enclosed in the substance of the mantle. The arms are alike, but unequal in length, and are united at their base by a broad web. They have two rows of suckers. The body is oval in form and covered with wart-like prominences.

The Common Octopus, found on the British shores (and now so familiar to us by the energetic exertions of Mr. Henry Lee, F.L.S., and the managers of the Brighton Aquarium) is, perhaps, the strangest of all the Cephalopodous class. Its bizarre figure and bright staring eyes, which never close, cannot fail to excite astonishment when seen for the first time, especially when employed in the act of walking on the floor of an aquarium, or in that of swimming by contraction of the membrane

connecting the arms. Like other Cephalopods, however, rapid locomotion is performed stern-foremost by the discharge of water backwards from the funnel.

The feet or tentacula appended to the head are by no means exclusively destined to effect locomotion; they are used, if required, as agents in seizing prey, and of so terrible a character are they, that, armed with these formidable organs, the "Poulpe" becomes one of the most destructive inhabitants of the sea; for neither superior strength nor activity, nor even defensive armour, is sufficient to save its victims from the ruthless ferocity of such a foe. A hundred and twenty pairs of suckers, more perfect and efficacious than the cupping-glasses of human contrivance, crowd the lower surface of every one of the eight flexible arms. If the Poulpe but touch its prey, it is enough; once a few of these tenacious suckers get firm hold, the swiftness of the fish is unavailing, as it is soon trammelled on all sides by the firmly holding tentacula, and dragged to the mouth of its destroyer. The shell of the lobster or crab is a vain protection, for the hard and crooked beak of the Cephalopod easily breaks to pieces the frail armour. (Rymer Jones.)



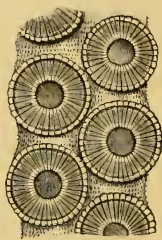
CROSS SECTION OF ARM OF OCTOPUS.

(For explanation of letters see text.)

Professor Owen thus describes the tentacles of the Poulpe, or Octopus:—"Each arm is perforated near the centre of its axis for the lodgment of its nerve (*a*, see woodcut) and artery (*b*): and upon making a transverse section of the arm, these are seen to be lodged in a quadrangular or rhomboidal space (*c*) of a light colour and apparently soft homogeneous texture, but in which a few radiating fibres may be discerned. This part is surrounded by four groups of transverse striae, forming as many segments of a circle, external to which there are two thin circular strata of fibres. On making a longitudinal section of the part, the striated segments are seen to consist of longitudinal muscular fibres, and of the surrounding strata, the fibres of the internal are longitudinal, and those of the external transverse. It is easy to conceive that, like the tongue in Mammalia, the arms thus organised may be lengthened, shortened, curved, and bent in all conceivable directions.

"The acetabula or suckers with which the internal surface of the arms of the Dibranchiates is provided, vary in relative position, in size, in structure, and in mode of attachment, not only in different species, but in different arms in the same individual, and sometimes in different parts of the same arm. Thus, in *Loligopsis veranii*, the suckers on the long cylindrical stem are sessile, while those on the expanded extremity are supported on long peduncles; and there is a remarkable instance of suckers having different structure for different functions in the same arm. In the Dibranchiate genera, which are characterised by a soft thin skin, as the Argonaut, Octopus, and Eledone, the suckers are soft and unarmed; in those genera which have a hard thick skin, as the Calamary and *Onychoteuthis*, hooks are developed in the cavities of the suckers."

"The circumference of the disc," says Dr. Roget, "is raised by a soft and tumid margin; a series of long slender folds of membrane, covering corresponding fasciculi of muscular fibres, converge from the circumference towards the centre of the sucker, at a short distance from which they leave a circular aperture. This opens into a cavity which widens as it descends, and contains a cone of soft substance rising from the bottom of the cavity, like the piston of a syringe. When the sucker is applied to a surface for the purpose of adhesion, the piston, having previously been raised so as to fill the cavity, is retracted, and a vacuum produced, which may be still further increased by the retraction of the plicated central portion of the disc. So perfect is the mechanism for effecting this mode of adhesion, that in the living Cephalopoda, while the muscular fibres continue contracted, it is easier to tear away the substance of the limb than to release it from its attachments: and even in dead animals the suckers retain a considerable power of adhesion."



SUCKERS OF OCTOPUS.

The Octopus is crepuscular in its habits, lying concealed in a rock cranny all day, and emerging at dusk in search of prey. Mr. Sylvanus Hanley, the well-known conchologist, who passes every winter

in Italy, states that there are living in the harbour of Leghorn several Octopods having arms at least four feet long, and as thick at their base as a man's wrist. They lie with their bodies squeezed into, and hidden in, crevices in the stonework of the mole and sea-wall, two or three of their arms extended and waving about in the water in readiness to seize passing prey, and the others holding fast to the blocks of stone. Mr. Hanley says that his son, who is a practised shore-hunter, and no coward, having frequent occasion, whilst in search of shells, to climb along a ledge of the rough masonry near the surface of the water, just beneath which was the lurking-place of one of these great creatures, was for some time afraid to pass the spot, in consequence of the animal's formidable appearance; for, as he approached, it would thrust one or two of its disc-studded arms out of water, and stretch them towards him in a threatening manner, in its endeavours to reach him. The Italian divers and bathers have a wholesome dread of these creatures.

The Octopus was the "polypos" of Homer and Aristotle. There can be little doubt that the "Hydra," with its hundred snake-like arms, was an Octopus. On a Greek tomb, at the British Museum, is a bas-relief representation of Hercules attacking the Hydra.

Mr. Darwin, in his narrative of the "Voyage of the *Beagle*," says, that whilst looking for marine animals, with his head about two feet above the rocky shore, he was more than once saluted by a jet of water, accompanied by a slight grating noise. At first he could not think what it was; but he afterwards found that it was an Octopus, which, though concealed in a hole, thus led him to its discovery; and it appeared to him that it could certainly take good aim by directing its tube or syphon on the under side of the body at the intruder.

Although, says Darwin, the Octopus is common at St. Jago in the pools of water left by the retiring tide, they are not easily caught. By means of their long arms and suckers, they can drag their bodies into very narrow crevices, and when thus fixed it requires great force to remove them. At others, they dart tail-first, with the rapidity of an arrow from one side of the pool to the other, at the same instant discolouring the water with a dark chestnut-brown ink. They also escape detection by varying their tints according to the nature of the ground over which they pass.

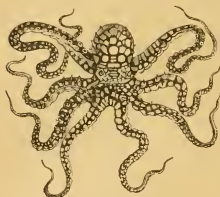
The following account of a marine diver, attacked by an Octopus, exhibits the behaviour of these animals towards any being that intrudes upon them in their native element:—

On 4th November, 1879, Mr. J. Smale, Government diver, was at work at the bottom of the tideway of the River Moynes, Melbourne. Having placed a charge of dynamite between two large stones, he came up and exploded it, and on descending again found one of the stones thrown out, which he sent up, and then hooked on to another, but could not start it, and having descended again, the current being pretty strong at the time, he stretched himself out on the stone, and reached his right arm down to feel if he could get another small charge under it, not being able to do this in any other position. "My arm," he says, "was scarcely down, however, before I found it was held by something, and the action of the water was stirring up the loose clay, and therefore I could not see distinctly for a few minutes, but when it did clear away I saw, to my horror, the arm of a large Octopus entwined round mine like a boa constrictor, and just then he fixed some of his suckers on the back of my hand, and the pain was intense. I felt as if my hand was being pulled to pieces, and the more I tried to take it away the greater the pain became, and, from past experience, I knew this method would be useless. But what was I to do, lying in this position? I had the greatest difficulty in keeping my feet down, as the air rushed along the interior of my dress and inflated it, and if my feet had got uppermost I should soon have become insensible, held in such a position, and if I had given the signal to be pulled up, the brute would have held on, and the chances would have been that I should have had a broken arm. I had a hammer down by me, but could not reach it to use it on the brute. There was a small iron bar not far from me, and with my feet I dragged this along until I could reach it with



COMMON OCTOPUS.

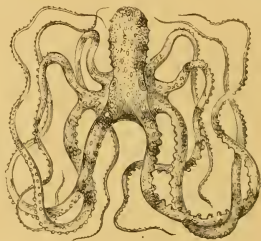
my left hand. And now the fight commenced; the more I struck him, the tighter he squeezed, until my arm got quite benumbed, but after a while I found the grip began to relax a little, but he held on until I had almost cut him to pieces, and then he relaxed his hold from the rock, and I pulled him up. I can assure you I was completely exhausted, having been in that position for over twenty minutes.



OCTOPUS HORRIDUS.

for, like the celebrated robber Peace, he was always to be found *at home* in the morning. But the rate at which he thinned the young Lump-fishes in an adjoining tank led to grave suspicion, and after too hearty a meal one evening he imprudently stayed out all night, and was 'caught red-handed,' gorged to distention, next morning, in the Lump-fishes' abode.

"On another occasion two Octopuses, kept in the same tank, also took to nocturnal roaming. Leaving their own residence after dark, one went east and the other went west, and, as if by preconcerted plan, neither was content merely to cross the frontier and visit his nearest neighbours, but both passed through, or over, one intervening tank, and settled down amongst the tribes beyond. One of them found himself in a Brobdingnag of crabs—a colony of giants too strong to be successfully invaded even by an armada of Octopods. If he had arrived at Lilliput instead—a tank inhabited by pigmy crustaceans—he would soon have depopulated it, by clutching in his hateful embrace more victims *per diem* than ever an unwelcome foul-mouthed dragon of old demanded as his daily dole of youths and maidens, to satisfy his inconvenient preference for their flesh as his daintiest dish. The other traveller found his way into Lobsterdom, and putting on a bold front, proceeded to attack the chief. The Lobster, though evidently alarmed, 'showed fight,' and the intruder was obliged to retreat, and seek refuge in a cranny of the rockwork. Although the Lobster which bore the brunt of the attack was a very large one, I was at the time surprised that it so decisively vanquished the invader as to save from destruction the other smaller specimens of its kind, which were its companions. For it is an old notion, still generally believed by fishermen, that if an Octopus approaches a 'pot' or 'stalker' in which are Lobsters that have been entrapped, they will cast off their claws, and become literally sick with fright.



OCTOPUS MACROPUS.

"In localities where the Octopus abounds, the crustacea probably learn to regard it as an enemy to be dreaded, but this is certainly not the case with those which I have had opportunities of observing. The common Crabs, on which this animal is habitually fed in the Aquarium, have no knowledge of their danger in its presence. When tossed into the tank, they frequently run towards the monster who is waiting to devour them, and even scramble on to and over his back. It may be that, as in countries previously unvisited by man, the birds and beasts, unacquainted with his destructive powers and carnivorous habits, show no fear of him at first sight, so the Crabs and Lobsters at Brighton so rarely see an Octopus in their native haunts, that they have not learned to recognise their deadly foe."†

* *Illustrated Australian News*. No. 183. Melbourne, Nov. 28. 1879; p. 187.

† Henry Lee; "Aquarium Notes."



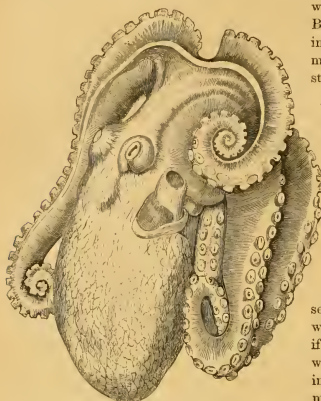
COMMON OCTOPUS.

Concerning the spawning of the Octopus, Mr. Lee writes:—"Our Octopus fortunately selected as a suitable site for her nest a recess in the rockwork, close to the front glass of the tank, so that her movements could be easily observed. Her body just filled the entrance to it; and she further strengthened its defences by dragging to the mouth of her cavern two dozen or more of living oysters, and piling them one on another to form a breastwork or barricade, behind which she ensconced herself. Over this rampart she peered with her great sleepless, prominent eyes; her two foremost arms extended beyond it; their extremities coiling and writhing in ceaseless motion, as if prepared to strike out right and left at any intruder. Her companions evidently felt that it was dangerous to approach an excited mother guarding her offspring, and none ventured to go within arm's length of her. Even her forlorn husband was made to keep his distance. If he dared to approach, with intent to whisper soft words of affection into his partner's ear, or to look with paternal pride on the newly-born infants, the lady roused herself with menacing air, and slowly rose till her head overtopped the barrier. By an instantaneous expansion of the pigment vesicles of the skin, a dark flush of anger tinged the whole surface of the body; the two upper arms were uncoiled and stretched out to their utmost length towards the interloper; and the poor snubbed, hen-pecked father, finding his nose put out of joint by the precious baby, which belonged as much to himself as to its fussy mother, invariably shrank from their formidable contact, and sorrowfully and sullenly retreated, to muse, perhaps, on the brief duration of cephalopodal marital happiness.

"The eggs of the Octopus when first laid are small, oval, translucent granules, resembling little grains of rice, and not quite an eighth of an inch long. They grow along and around a common stalk, to which every egg is separately attached, as grapes form part of a bunch. Each of the elongated bunches is affixed by a glutinous secretion to the surface of a rock or stone (never to seaweed, as has been erroneously stated), and hangs pendant by its stalk in a long white cluster, like a magnified catkin of the filbert, or, to use Aristotle's simile, like the fruit of the white alder. The length and number of the bunches vary according to the age and condition of the parent. Those produced by a young Octopus are seldom more than about three inches long, and from twelve to twenty in number; but a full-grown female will deposit from forty to fifty such clusters, each about five inches in length. I have counted the eggs of which these clusters are composed, and find that there are about a thousand in each: so that a large Octopus produces in one laying, usually extending over three days, a progeny of from 40,000 to 50,000. Our brooding French Octopus, when undisturbed, would pass one of her arms beneath the hanging bunches of her eggs, and dilating the membrane on each side of it into a boat-shaped hollow, would gather and receive them in it as in a trough or cradle, exhibiting in its general shape and outline a remarkable similarity to that of the Argonaut, or Paper Nautilus, with the eggs of which Octopod its own are almost identical in form and appearance. Then she would tress and gently rub them, occasionally turning towards them the mouth of her flexible exhalant locomotor tube, like the nozzle of a fireman's hose-pipe, so as to direct upon them a jet of the ex-current water. I believe that the object of this syringing process is to free the eggs from parasitic animalcules, and possibly to prevent the growth of conferva, which I have found rapidly overspread those removed from her attention. Week after week she continued to attend to them with the most watchful and assiduous care, seldom leaving them for an instant, except to take food, which, without a brief abandonment of her position, would be beyond her reach. Aristotle asserts that while the female is incubating she takes no food. This is incorrect. In the tank with our specimen were seven others of her species, and to supply them with food about five-and-twenty living Shore-crabs (*Carcinus maenas*) were daily tossed into it. Although she so seldom left her nest, she generally obtained her share of these, and would seize with her suckers, and draw towards her, sometimes three at a time, one by each of three of her arms. Their shells were soon broken and torn apart by her powerful beak, and when she had devoured the contents the hard *débris* was cast out of her den.

"At the end of the fifth week from the deposit of her ova she began to exhibit considerable irritation and restlessness, in consequence of the annoyance she experienced from visitors trying to rouse her to movement, or to frighten her from her eggs, by knocking at the glass with coins or sticks, and flouting pocket-handkerchiefs in front of her. I found that on some of

these occasions, in her excitement whilst protecting her eggs from the supposed danger, she had torn away the lower portion of some of the clusters, and that their number was considerably diminished. It therefore became necessary to screen her from the public gaze. Fearing also that, notwithstanding the cessation of the interruption to which she had been subjected, she might by her over-fussiness destroy the remainder of her progeny, a portion of her eggs



OCTOPUS REPOSING.

(After a drawing by Mr. T. Davidson, F.R.S.—Frontispiece of Mr. Henry Lee's "The Octopus.")

were removed, and transferred to a smaller tank. By the removal of these eggs I hoped also that an interesting question concerning their development might be finally answered. Aristotle had been understood to affirm that the parent Octopus 'incubates'

her eggs. I had always expressed very decidedly my opinion, derived from previous experiments on the eggs of the Cuttle-fish and Squid (*Sepia* and *Loligo*), that the ova once impregnated no incubation by the parent is required, or takes place, in a sense, equivalent to that of a fowl developing a chick by the warmth of its body, but that her unremitting attention to them is solely for the purpose of protecting them from injury, keeping them free from animal and vegetable parasites, and preventing their being devoured by fishes.

"The eggs which were taken away on the forty-second day from their extrusion for special inspection were successfully hatched, and I do not doubt that if they could have been kept free from parasites this would have taken place if they had been detached immediately after they were laid. The young Octopods made their appearance on the 8th, 9th, and 10th of August, the eggs had been extruded on the 19th, 20th, and 21st of June, and thus, although it was proved as I expected, that the development of

the embryo does not depend on incubation, the accuracy of Aristotle's statement that its period in the egg is fifty days was completely and satisfactorily confirmed.

"The young Octopus fresh from the egg is of about the size of a large flea, and when irritated is nearly of the same colour. It is very different in appearance from an adult individual of the same species. At first sight it is more like a *Sepia*, without its tentacles, than an Octopus. The arms, which will afterwards be four or five times the length of its body, are so rudimentary as to be even shorter in proportion than the pedal arms of the Cuttle-fish, and appear only as little conical excrescences, having points of hair-like fineness, and arranged in the form of an eight-rayed coronet around the head.

"At this early stage of its existence the young Octopus seeks and enjoys the light which it will, later in life, carefully shun. It manifests no desire to hide itself in crevices and recesses, as the adult does, but swims freely about in the water, often close to the surface, propelling itself backward by a series of little jerks caused by each stroke of the force-pump, which expels a jet of water from the out-flow pipe of the siphon."*

"It is a not uncommon occurrence," says Mr. Henry Lee, "that when an Octopus is caught, it is found to have one or more of its arms shorter than the rest, and showing marks of having been amputated, and of the formation of a new growth from the old cicatrix. Several such specimens have been brought to the Brighton Aquarium, one of which was particularly interesting. Two of its arms had evidently been bitten off about four inches from their base; and out from the end of each healed stump grew a slender little piece of newly-formed arm, about as large as a lady's stiletto, or a small button-hook—in fact, just the equivalent of worthy Capt. Cuttle's iron hook, which did duty for his lost hand.

* "Aquarium Notes on the Octopus," by Henry Lee, F.L.S.

"This reparative power is possessed by some other animals, of which the Star-fishes and Crustacea are the most familiar instances, such as the common 'Five-finger' (*Uraster*), and the Brittle-star (*Ophiocoma*), both of which can throw off their limbs and grow them again; the act is voluntary, and the dismemberment complete. The only joint from which new growth can start in the Crustacea is that connected with the body. The whole limb must be got rid of. The Octopus, on the contrary, is incapable of voluntary dismemberment, but has the faculty of reproducing, as an out-growth from the old stump, any portion of an arm (or leg) which may have been lost by misadventure. I say 'arm or leg,' for one hardly knows which these eight appendages should be called.

"There lingers still among the fishermen of the Mediterranean a very ancient belief that the Octopus, when pushed by hunger, will gnaw and devour portions of its own arm. Aristotle knew of this, and positively contradicted it; but a fallacy once planted is hard to eradicate. The fact is, that the larger predatory fishes regard the Octopus as very acceptable food, and there is no better bait for many of them than a portion of one of its arms. Some of the Cetacea also are very fond of them, and whalers have often reported that when a 'fish,' as they call it, is struck, it disgorges the contents of its stomach, amongst which they have noticed parts of the arms of Cuttle-fishes, which, judging from the size of their limbs, must have been very large indeed. The food of the Sperm Whale consists largely of the gregarious Squids, and the presence in 'spermaceti' of their undigested beaks is accepted as a test of its being genuine. That old fish-reptile, the *Ichthyosaurus*, also preyed upon them; and portions of the horny rings of their suckers were discovered in its coprolites by Dean Buckland.

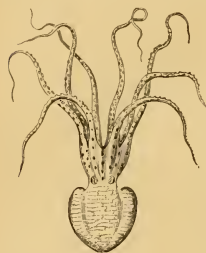
"Amongst the worst enemies of the Octopus in British waters is the Conger. They are both rock-dwellers, and if the voracious fish come upon his cephalopod neighbour unseen, he makes a meal of him, or, failing to drag him from his hold, bites off as much of one or two of his arms as he can conveniently obtain. The Conger, therefore, is generally the author of the injury which the Octopus has been unfairly accused of inflicting on itself. The Curator of the Havre Aquarium describes an attack by Congers on an Octopus which he had thrown into their tank. As soon as the latter touched the bottom it examined every corner of the stonework. The moment it perceived a Conger it seemed to feel instinctively the danger which menaced it, and endeavoured to conceal its presence by stretching itself along a rock, the colour of which it immediately assumed. Finding this useless, and seeing that it was discovered, it changed its tactics, and shot backwards, in quick retreat, leaving behind it a long black trail of turbid water, formed by the discharge of its ink. Then it fixed itself to a rock, with all its arms surrounding and protecting its body, and presenting on all exposed sides a surface furnished with suckers. In this position it awaited the attack of its enemies. A Conger approached, searched with its snout for a vulnerable place, and having found one, seized with its teeth a mouthful of the living flesh. Then, straightening itself out in the water, it turned round and round with giddy rapidity, until the arm was, with a violent wrench, torn away from the body of the victim. Each bite of the Conger cost the unfortunate creature a limb, and, at length, nothing remained but its dismembered body, which was finally devoured, some Dog-fishes, attracted by the fray, partaking of the feast.

"An Octopus was once placed in the Brighton Aquarium with some 'Nursehounds,' or 'Larger spotted Dog-fishes' (*Scyllium stellare*); for a while, they seemed to dwell together as peaceably as the 'happy family' of animals that used to be exhibited in a travelling cage at the foot of Waterloo Bridge, the Octopus usually remaining within the 'Cottage-by-the-sea' which he had built for himself in the form of a grotto of living oysters, and the Dog-fish apparently taking no notice of him. But one fatal day the 'Devil-fish' was missing, and it was seen that one of the 'companions of his solitude' was inordinately distended. A thrill of horror ran through the corridors. There was suspicion of crime and dire disaster. The corpulent Nursehound was taken into custody, lynched and disembowelled, and his guilt made manifest. For there, within his capacious stomach, unmutated and entire, lay the poor Octopus who had delighted thousands during the Christmas holidays. It had been swallowed whole, and very recently, but life was extinct."*

* "The Octopus; or, the Devil-fish of Fiction and of Fact," by Henry Lee, F.L.S. For most of the facts and statements here recorded concerning the Octopus, the writer is indebted to his friend Mr. Henry Lee.—H. W.

There are forty-six species of Octopus known to naturalists, and their distribution appears to extend to all the rocky coasts, both in the temperate and tropical regions of the earth.

The *Pinnoctopus*, or finned Octopus, discovered by MM. Quoy and Gaimard on the coast of New Zealand, exceeds three feet in length. Its body is furnished with two lateral fins united behind.



PINNOCTOPUS.

The *Eledone*, like the Octopus, is found on British coasts and also on the shores of the Mediterranean and as far north as Norway. It has only a single row of suckers on each arm. It is diminutive in size as compared with its cousin the Octopus. One species (*Eledone moschata*) emits a musky smell when irritated or disturbed.

All the species of Octopus possess the faculty shared by certain fishes, and by the Chamæleon, of varying the colour of their bodies to correspond with the hue of the rocky or sandy shore on which they desire to lie concealed. They also change colour remarkably when irritated, becoming as it were "flushed," like an angry school-boy. The *Eledone* makes itself of a peculiarly heightened colour when angry.

In *Cirrotheuthis* the body is furnished with two transverse fins, whilst the eight arms or tentacles are joined by a web-like expansion of the body-membrane, so as to form a small inverted parachute or umbrella, for the capture of its prey. This is one of the most northern species of Cephalopods known: the single species *C.*

mulleri inhabiting the coasts of Greenland. It has no shell. Its colour is violet, and it is only ten inches in length.

Philonexis is the smallest of all the Octopods, being from one to three inches in length. It is gregarious in habits, and is one of the few Octopi which have been met with in the open sea, in the Mediterranean, and the Atlantic. Its arms support two rows of suckers. It feeds on small floating mollusca.

Lastly, the *Tremoctopus*, which has its arms partially, or all, webbed half-way up, is remarkable for possessing two large aquiferous pores (or *tremata*) on the back of the head. *Tremoctopus* is a free-swimming Cephalopod, met with in the Atlantic and Mediterranean.

Darwin states that the living Octopods are slightly phosphorescent in the dark. The Octopus, when at rest, curls its dorsal arms over its back, like the Argonaut, shadowing forth, as Forbes believed, the origin and relation of the shell.

About 1780, Denys de Montfort published a work entitled "*Historie Naturelle Générale et Particulière des Mollusques*," in which, at Vol. II., p. 256, he gives a representation of a gigantic Octopus throwing its arms over a three-masted vessel. It is stated that he said to his colleague, M. DeFrance, "If my entangled ship is accepted, I will, in my next edition, represent it embracing the Straits of Gibraltar, or capsizing a whole squadron of ships." (D'Orbigny.)



CIRROTHEUTHIS MULLERI.

Although the Cephalopods are seldom eaten in Great Britain, they are appreciated as food by nearly all other maritime nations. Along the western coast of France, and in the countries bordering on the Mediterranean and Adriatic, they form a portion of the habitual sustenance of the people, and are regularly exposed for sale in the markets, both in a fresh and dried condition. Salted Cuttles and Octopus are there eaten during Lent as commonly as salted Cod are brought to table in England on Good Friday; and, thus prepared, generally form a portion of the provisions supplied to the Greek fishing-boats and coasters. "During Advent and Lent, the Octopus is largely consumed by the Orthodox Greek Catholics, amongst whom the use of fish and meat is prohibited in those seasons of abstinence. This strange diet is chiefly obtained from Tunis, and in the Levant and Greek markets its trade name is 'octopodia,' or 'polypi.' In a good season, the Island of Karkenah supplies about

150 tons of polypi; and the Jerbah waters a third of this quantity. The remaining coast and islands may be calculated to furnish a minimum of 650 cwt. to 700 cwt. of dried Cuttle-fish.

"The Octopods prefer the rocky shallows, and are found in those waters, coming from the open sea to deposit their eggs in the months of January, February, and March; but a considerable number remain permanently near the shore.

"In deep water they are taken by means of earthen jars strung together and lowered to the bottom of the sea, where they are allowed to remain for a certain number of hours, and into which the fishes introduce themselves. Frequently from eight to ten Octopods are taken from every jar, at each visit of the fishermen. In less deep water, earthenware drain pipes are placed side by side for distances frequently exceeding half a mile in length, and in these also the Octopods enter, and are subsequently captured. As they are attracted by all white, smooth, and bright substances, the natives deck places in the creek and hollows of the rock with white stones and shells, over which the polypi spread themselves, and so are caught from four up to eight at a time."*

SECTION B.—DECAPODA.

FAMILY III.—TEUTHIDÆ.

Leaving the eight-footed division of two-gilled Cephalopods, we come next in order to the ten-footed family of the *Teuthidæ*,† the name applied by Aristotle to the Calamaries and Squids.

This embraces a very extensive and most interesting series, remarkable not only for the symmetry of their forms, but also as numbering among them some of the largest members of the whole order, the veritable "Anakims and Nephilim," the giants of the Molluscan kingdom.

Besides the eight ordinary feet possessed by the Octopods, these Decapods, or ten-footed forms, are furnished with two greatly-elongated tentacles, having expanded club-shaped extremities covered with suckers. The eight ordinary feet are comparatively shorter than those of the Octopods; the dorsal pair being usually the shortest, and the ventral the longest. The tentacles take their origin within the circle of these eight feet, between the third and fourth pairs; in *Cheiroteuthis* they are six times as long as the animal itself. In *Sepia*, *Sepioloa*, and *Rossia* they are completely retractile into large sub-orbicular pouches. In *Loligo* and *Sepioteuthis* they are partially retractile; but in *Cheiroteuthis* they are non-retractile. They serve, like the lasso of the American Indian, to seize their prey, when beyond the reach of the ordinary arms, or to moor the animal to any floating objects, or for safety during the agitation of a stormy sea.

The suckers of the Calamaries differ from those of Octopus, &c., the latter being fixed flat upon the tentacles, whilst the former are supported on peduncles or foot-stalks; they are, moreover, bordered by a horny ring which is finely serrated at the edge. The eyes, which are large, are movable in their sockets, giving them a weird and "uncanny" aspect. In most of this group, the funnel is furnished with an internal valve.

The shell in the Calamaries is delicate, translucent, and horny, and called the "pen," or the *gladius* (sword); in the Cuttle fishes it is a calcareous "bone" (so-called), or *sepiostaire*. In the genus *Spirula* it is a delicate spiral tube, divided into chambers by a series of nacreous partitions (*septa*). In all, it is internal. Yet, with the exception of *Spirula*, it is not attached to the animal by any muscles, but is only loosely lodged in the middle of the back of the mantle. So loosely does it lie within this cavity, that when the body is cut open it readily falls out. The fossil forms, as we shall presently see, have other modifications of their shells, but all are internal.

Like the gregarious fishes which frequent the open sea, the Squids and Cuttles appear periodically in great shoals on the coasts and banks. This migratory instinct is connected either with the pursuit of particular food, or, as is more frequently the case, it is caused by the females seeking suitable places for spawning. The integument, or skin, of all is provided with *chromatophores*, which are sacs with elastic walls, full of pigment, and provided with radiating muscles, by which they may be drawn out to a size many times greater than that which they occupy in their contracted state. In their dilated condition, the colour proper to the contained pigment becomes plainly visible, while in their contracted state they appear as mere dark specks. It is to the successive expansion and contraction of these

* Report on Tunisian Fisheries, by Mr. W. K. Green, H.B.M. Consul at Tunis.

† *Teuthidæ*—the "Squid" tribe.

chromatophores that the Cephalopoda owe the peculiar play of "shot" colours, which pass like blushes over their surface in the living state. These blushes of colour are especially well displayed by young Cephalopoda just freed from the egg. (Huxley.)*

The Common Squid (*Loligo vulgaris*) is met with in shoals around the Cornish coast, and is taken by the fishermen at night by torchlight in large numbers for bait. Its body is cylindrical, tapering behind and much elongated in the males; the fins are terminal and united at the base of the body forming a rhomb. The mantle is supported by two ridges in front, and there is a dorsal groove fitting the ridge and grooves on the neck of the funnel. The eyes are large and covered by the skin. The feet are of unequal length, the dorsal ones being the shortest; they are armed with two rows of suckers, furnished with horny dentated margins. The tentacles are partly retractile, with lanceolate club-like extremities bearing four rows of cupping-suckers. These animals are called by the fishermen "pen and ink fish," from the readiness with which they discharge their ink-bag when alarmed or in danger of being captured, and also from the fact of the delicate internal shell (or *gladius*) of the Calamary (*Loligo vulgaris*) being in shape extremely like a quill-pen, with an expansion on each side to correspond with the vane of the feather. These delicate pens are multiplied by age, several being found packed closely one behind another in old individuals. (Owen.) The Calamaries are all good swimmers, and gregarious in their habits; they can also crawl head-downwards on their oral disc, or mouth, with the feet expanded. The species of *Loligo*, about nineteen in number, are cosmopolitan in distribution, being found throughout the seas of the globe, living both in the open sea and along the coasts.

The spawn of the Squid (*Loligo vulgaris*) consists of dozens of semi-transparent, gelatinous, slender, cylindrical sheaths, about four or five inches long, each containing many ova embedded in it, and all springing from one common centre, and resembling a mop without a handle. Johann Bodasch, Professor of Natural History at Prague, calculated that one of these mop-like masses contained 39,766 ova; and by counting those embedded in ten of the long, gelatinous, finger-like processes, and weighing them and the remainder, Mr. Henry Lee verified his estimate, and computed that in one specimen there were 42,000 perfect young Squids. It is evident that comparatively few of them live to arrive at maturity, or the sea would teem with them; and in every existing aquarium it has been found impossible to rear the young Cephalopods hatched there. These "sea-mops" are not found attached to anything, and the pelagic habits of the Calamaries render it probable that they are left floating on the surface of the ocean.

"The movements of the Little Squid" (*Loligo media*), says Mr. Henry Lee, "are very graceful and pleasing. They are gregarious, like other Squids, and keep close together. By the action of their tail fins they can either 'go a-head' or 'turn astern,' and it is very interesting to watch their manœuvres. We once had in one of the tanks four of these little Squids (which were only four inches long), and I was much amused by seeing them perform, in a most ludicrous manner, the quadrille figure called *La Trenise*. Three of them ranged themselves side by side, and advanced towards, and retired from, a solitary one, who, for some reason, was not received into their rank, but faced them. When they withdrew, stern first, to the back of the tank, the lonely one followed them up with a *pas seul*. But there the similitude ended. He was repeatedly driven backwards to his former position, and was not allowed the privilege of taking his partner with him.

"These little Squids," he adds, "are impudently voracious. I have seen one in single combat with a young Dog-fish about four inches long. At first I thought the fish was the aggressor, and had seized one of the tentacular arms of the little *Loligo* as a good substitute for a worm; but it was soon apparent that the affray had been provoked by the carnivorous Cephalopod, and that the puppy-fish would get the worst of it; so they were separated."

* In the Dibranchiata (Squids, Cuttles, Octopus, &c.), the three principal pairs of nerve-masses, or ganglia, are usually large, and so closely aggregated together, that they are not readily distinguishable. The optic nerves are very large; one or two nerves are given off to the ganglion of the throat and mouth, which are united to form one mass encircling the gullet. The pedal, or foot-ganglion, lies on the posterior side of the gullet, and supplies the large nerves to the arms (feet) or tentacles, and those to the funnel, while the auditory nerves are immediately connected with them. The other nerve-centres (called *parieto-splanchnic*) give off branches to the mantle, the shell-muscles, the branchia, the heart, and other internal organs; the inferior buccal ganglion sends nerves along the oesophagus, which end in a ganglion on the stomach. (Hancock, *Anatomy of the Ommastrephes*.)

A species of Calamary found on the coast of Greenland, the *Gonatus amœna*, which, in the form of its pen and of the animal itself, resembles *Loligo* in most respects, has four series of cups on its eight *poda*, or feet, and on its two long tentacular feelers it has numerous small cups, and a single large fixed cup armed with a hook.

The *Sepioteuthis*, of which thirteen species are known, is also closely related to *Loligo*. It has lateral fins as long as the body, and sometimes attains to three feet in length. It is widely distributed geographically from the West Indies to the Cape, the Red Sea, Java, and Australia.

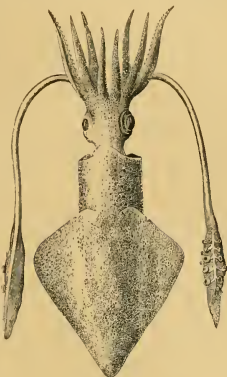
A singular little form, only two inches in length, named *Cranchia* (in honour of Mr. J. Cranch, Naturalist to the Congo Expedition), has been met with in the open sea off the West Coast of Africa. It makes the nearest approach in general character and form to the Octopods, of any of this division of Calamaries. Its pen is long and narrow, its body large and globular, the head is very small, and the eyes are fixed. The feet are short and have two rows of suckers. The tentacular clubs have four rows of cups, and are finned behind. The funnel is furnished with a valve. Only two species are known, of which *Cranchia scabra* is the type.

One of the most diminutive of the Teuthidæ is the *Sepiola rondelleti* of Gesner, a veritable Lilliputian among Squids, sometimes caught on the south coast of England in Shrimp-nets. The mantle-sac enclosing the body of this little "Tom Thumb" Cephalopod is about an inch in length, and in shape like a short wide-bore mortar. The head may be supposed to be the tampion fixed in the muzzle; and where the trunnions would be are two little flat fins of rounded outline. The large goggle eyes seem to be out of all proportion to the size of their owner; but they are, apparently, "all the better to see with," either to watch for a tender young Shrimp coming within arm's reach, or to perceive an approaching enemy. *Sepiola*, like its comparatively Brobdignagian relatives, has the faculty of rapidly changing colour, and, if angered or alarmed, its hue is almost instantaneously altered from pale parchment dotted with pink to a deep reddish-brown. In its habits this little animal differs as much from the Sepia as the latter from the Octopus. It naturally buries itself up to its eyes in the sand; but as sand is apt to harbour impurities, which in a bowl or tank become corrupt and generate poisonous sulphuretted hydrogen, the bottom of these receptacles is usually covered with fine shingle. It is most interesting to notice, how, in obeying its burrowing propensities, the *Sepiola* adapts itself to circumstances, and entirely deviates from its customary mode of procedure. To make a sand pit for its hiding-place, it will direct upon it strong jets of water from its funnel, and thus blow out a cavity in which to seat itself, and allow the disturbed particles of sand to settle over and around it; but as the pebbles are too heavy to be thus displaced by its blasting apparatus, it removes them, one at a time, by means of its arms, which are long and strong in proportion to its little short body. (Henry Lee.)

The pen of *Sepiola* is half as long as the back of the animal. Six species of this minute Squid are known from the coasts of Norway, Britain, the Mediterranean, the Mauritius, Japan, and Australia.

A sub-genus of *Sepiola*, named *Rossia*, by Owen (after Captain Sir James Ross, R.N.), attains a length of from three to five inches, and is represented by six species, one of which is found as far north as Regent Inlet, the others being from Great Britain, the Mediterranean, and Manila.

Another pelagic Squid, named *Loligopsis*,* by Lamarck, has a very elongated tapering body, with short arms, provided with two rows of cups. Its tentacles are very slender; they are often mutilated or wholly wanting. Its caudal fin is rhomboidal, and reminds one of the blade of a screw-propeller. Its pen, which is slender, has a minute conical appendix to its extremity. Eight species of *Loligopsis* are

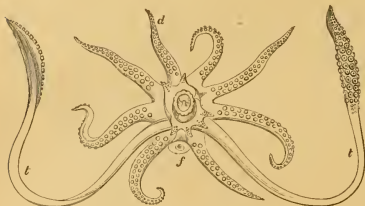


COMMON SQUID.

* From *Loligo*, and *opsis*, Gr., look.

recorded, all dwellers in the open sea, and therefore good swimmers. They occur in the Atlantic, from the Arctic seas to Madeira, in the Mediterranean, the seas of India and Japan, and even in the South Sea, and attain a length of from six to twelve inches.

A very interesting member of this family is named *Cheirotenthis*.* Although the length of its body is often less than three inches, its tentacular arms measure three feet in length, and its other arms eight inches to one foot. Its ventral arms are longest. Its long slender tentacles have single cups or suckers scattered at distant intervals along their stalks, and four rows of pedunculated claws on their expanded extremities. The pen, which is slender, is slightly winged at both ends. The fin is broadly rounded, and pointed at its extremity. Two species are described, one of which has been met with in the Mediterranean, the other on the Gulf-weed in mid-Atlantic.



BUCCAL ASPECT OF COMMON SQUID. (After S. P. Woodward.)
d, Dorsal Feet or Arms; f, Funnel; t, t, Tentacles.

feet, with the exception of the ventral pair, are webbed high up, thus forming a semi-parachute. The tentacles are long, and placed outside the web formed by the union of the three dorsal pairs of feet; the ends of the tentacles are armed with six rows of cups or suckers with dentated borders. The pen is short and broad-bladed, like an old bronze arrow-head in shape. Two forms of this genus inhabit the Mediterranean in the open sea.

The Clawed Calamary (*Onychoteuthis* †) has an elongated, cylindrical body, terminating in a broadly-expanded, rhombic, somewhat-pointed caudal fin. The feet are unequal, with two rows of suckers on each. The tentacula are long and powerful, the club-shaped extremity being armed with a double series of hooks, and having usually a small group of suckers at the base. The shell, which is narrow, terminates in a slender, hollow, conical point.

Perfect as is the apparatus of suckers, with which the prehensile organs of the Dibranchiate division of the Cephalopoda are provided, still, it would seem, there are circumstances in which even these would be insufficient to enable their possessor to fulfil all the offices in the economy of nature for which it was designed; and in those species which have to contend with the agile, slippery, and mucous clad fishes, more powerful organs of prehension are superadded to the suckers.

In the Calamary the base of the piston of each sucker is enclosed by a horny hoop, the outer and anterior margin of which is developed into a series of sharp-pointed, curved teeth. These can be firmly pressed into the flesh of a struggling prey by the contraction of the surrounding transverse fibres, and can be withdrawn by the action of the retractor fibres of the piston. Let the reader picture to himself the projecting margin of the horny hoop developed into a long, curved, sharp-pointed claw, and these weapons clustered at the expanded terminations of the tentacles, and arranged in a double alternate series along the whole internal surface of the eight muscular feet, and he will have some idea of the formidable nature of the carnivorous *Onychoteuthis*.



LOLIGOOPSIS VERMICULARIS.

We cannot quit this part of our subject without noticing a structure which adds greatly to the prehensile powers of these uncinated Calamaries. At the extremities of the long tentacles, in addition to the clawed suckers, a cluster of small, simple, unarmed suckers may be observed at the base of each of the expanded, club-like extremities. When these small, simple suckers are applied

* *Cheir*, Gr., a hand, and *Gr.*, *teuthis*, a Squid.

† *Histon*, Gr., a veil, and *teuthis*

‡ *Onyx*, Gr., a claw, and *teuthis*.

to one another the tentacles are firmly locked together at that part, and the united strength of both the elongated peduncles can be applied to drag towards the mouth any resisting object which has been grappled by the terminal hooks. There is no mechanical contrivance which surpasses this structure. The obstetric forceps, invented by Sir J. Y. Simpson (in which either blade can be used separately, or, by the interlocking of a temporary joint, be made to act in combination), is stated to have been suggested by these tentacular arms of the Calamary. [Owen.] Specimens have been taken of this form varying in length from four inches to two feet. Six species belonging to this genus have been described, which, like so many of its congeners, have been met with in seas as broad as the Atlantic, the Pacific, and the Indian Ocean. These uncinated or Clawed Calamaries are solitary animals, frequenting the open sea, and especially the banks of floating gulf-weed in the "Sargasso Sea." *O. banksii* ranges from Norway to the Cape and Indian Ocean; the rest are confined to the warmer seas. *O. dussumieri* has been taken when swimming in the open sea 200 leagues north of the Mauritius.

The Armed Calamary (*Enoploteuthis**) approaches in size to that of the largest Cephalopods, of which we shall presently speak. It is probably six feet in length (if not larger) when adult; but it seems doubtful whether there is any very exact limit to the growth of some of these larger forms, if they happen to survive their infancy and youth without coming to an untimely end. The pen in *Enoploteuthis* is lance-shaped, but the feet, instead of being furnished with cups or suckers, have each a double series of strongly-curved, horny hooks, concealed by retractile webs. The tentacles are long and feeble, and evidently do not play an important part in the economy of the animal as in the clawed Calamary. Banks and Solander, in Cook's first voyage, found the dead carcass of a gigantic species of this kind floating in the sea between Cape Horn and the Polynesian Islands, in latitude 30° 44' S., longitude 110° 33' W. It was surrounded by aquatic birds, which were feeding on its remains. From the parts of this specimen, which are still preserved in the Hunterian Collection, and which have always strongly excited the attention of naturalists, it must have measured at least six feet from the end of the tail to the end of the tentacles. The natives of the Polynesian Islands, who dive for shell-fish, have a well-founded dread and abhorrence of these formidable Cephalopods, and one cannot feel surprised that their fears should have perhaps exaggerated the dimensions and destructive attributes of those creatures.

Ten species have been described belonging to this genus from the Mediterranean and the Pacific. Fossil hooklets arranged in rows, which, doubtless, belonged to a species of *Enoploteuthis*, a great, great ancestor of the one brought home by Sir Joseph Banks, have been met with fossil in the Lias formation of Lyme Regis, in Dorsetshire, and are now preserved in the British Museum of Natural History.

The Sagittated Calamary (*Ommastrephes*†) is a remarkably active member of a restless and cosmopolitan race. The sailors call them "sea-arrows," or "flying Squids," from their habit of leaping out of the water, often to such a height as to fall on the decks of vessels. Colonel Sykes records the fact that in returning from India, while the wind was light and the sea calm, several of these "flying Squids" leapt on board the vessel, falling upon the deck.‡ The body of the Sagittated Calamary is cylindrical, and has a large terminal rhombic fin. The feet have two rows of suckers, and sometimes an internal membranous fringe. The tentacles are short and strong, and armed with four rows of cupping suckers. The pen has a shaft with three diverging ribs and a hollow conical extremity. They vary in length from one to four feet. Fourteen species of these Sagittated Squids have been described from the Atlantic, Mediterranean, Indian, and Pacific Oceans. They are all gregarious in their habits, and frequent the open sea in all climates.

Gould gives the following interesting description of the Sagittated Calamary:—"Their usual mode of swimming is by dilating the water-breathing chamber of their sac-shaped body, and filling it with water. The body is then suddenly contracted, and the water forcibly ejected, so as to propel them backwards with great rapidity. So swift and straight is their progress that they look like arrows



PEN OF THE CALAMARY.

* *Enoplos*, Gr., armed.

† *Omm*, Gr., the eye, and *strepho*, Gr., I turn.

‡ *Proceedings of the Zoological Society*, 1833, p. 90, Plate 1.

shooting through the water. Whenever they strike the shore they commence pumping the water with increased violence, while every effort only tends to throw them still farther upon the sands, until they are left high and dry. The body is beautifully spotted with colours, which seem to vary with the emotions of the animal. At one moment they appear to be of a vivid red, at the next a deep blue, violet, brown, or orange. They devour immense numbers of small fish, and it is amusing to watch their movements, and see how, at a distance of several feet, they will poise themselves, and in an instant, with the rapidity of lightning, the prey is seized in their long arms and instantaneously devoured. They, in their turn, are a prey to the larger fishes."

On the coast of Newfoundland the bait used for the Cod-fishery at the commencement of May is the Herring; during June, July, and August the Capelin; and about the end of August and throughout September they use the Squids, which come into the bays in great abundance. They are caught by means of a "jigger," which is a conical piece of lead, round the circumference of the base of which are inserted eight or ten hooks. The fishermen go out in punts Squid-jigging of an evening, to catch bait required for the next day's fishing. About 100 or more Squids are caught by each boat, and thousands of them are taken during the season about 150 or 200 yards from the shore, in tolerably deep water. In many stations more than a dozen boats are engaged in Squid-catching. All parts of the Squid are cut up and used as bait; what is not required the next day is thrown away, or given to the pigs. In the northern district, the fishing spots are between Cape Freels and Cape St. John. The fishing takes place about sun-down. The Squid used so abundantly for bait in the Cod-fishery is *Ommastrephes sagittatus*.

The Squid is of an oblong cylindrical form. The length of the body is from eight inches to a foot, and it is about two inches in diameter. The flesh is said by the fishermen to be remarkably good eating, and to be excellent when fried. About the end of September the Squid disappears.

A crew of three men usually take from 100 to 500 in a day. The Squids come into the bay in such vast shoals that sometimes, during violent gales, hundreds of tons of them are thrown up together in beds on the flat beaches, and their decay spreads an intolerable effluvia around.

The following accounts of the capture of specimens of giant Cephalopods, although necessarily imperfect, and in many instances incapable of careful and complete correlation with one another, suffice to prove that there exist in the North Atlantic numerous living examples of ten-armed Calamaries, of a size surpassing any other members of the Molluscan class.

Some of these may be referred to *Loligo* and *Ommastrephes*; the majority, however, are no doubt properly to be referred to the *Architeuthis monachus* and *A. dux* of Steenstrup, and in this opinion Professor Verrill, who has examined much of the evidence and many of the actual specimens obtained from Newfoundland, agrees. His figures, prepared from photographs and from drawings of parts of several specimens, show it to have had a broadly-expanded internal pen, in form somewhat like that of the ancient genus *Teulopsis*, found fossil in the Jurassic formation. The tail-fin was broadly sagittate, or arrow-shaped, and finely pointed at its extremity. The arms had two rows of stalked suckers, and the tentacles, which were of great length (twenty-four feet), were remarkably slender, and had their expanded extremities armed with four rows of stalked suckers, with horny serrated borders.*

In a letter to the late Dr. S. P. Woodward, Dr. Mörch states that, according to an old Icelandic chronicle, a "sea spectre" (*Ommastrephes*) was driven ashore in 1639, as long and big as a man. It had seven tails, upwards of two yards long (the eighth was very likely lost), and one very long tail (one of the two tentacles, the other being lost), four to five fathoms long. The tails were crowded with buttons, like eyes, with a pupil and eyelid, which were gilt. This evidently refers to the suckers.

On the 26th of April, 1875, a very large Calamary was met with on the north-west of Boffin Island, Connemara. The crew of a "curragh" (a boat made like a "coracle," with wooden ribs covered with tarred canvas) observed to seaward a large floating mass surrounded by gulls. They pulled out to it, believing it to be a wreck, but to their astonishment found that it was an enormous Cuttle-fish, lying perfectly still, as if basking on the surface of the water. Paddling up with caution, they lopped off one of its arms. The animal immediately set out to sea, rushing through the water at a tremendous pace. The men gave chase, and, after a hard pull in their frail canvas craft, came

* "American Journal of Science and Arts," 1874, 3rd ser., vol. vii., p. 158; 1875, vol. ix., pp. 123, 177, plates ii.-v.

up with it, five miles out in the open Atlantic, and severed another of its arms and the head. These portions, labelled *Architeuthis duc*, can now be seen in the Dublin Museum. The shorter arms measured each eight feet in length and fifteen inches round the base. The tentacular arms are said to have been thirty feet long.*

In 1861 the French steamer *Alecton* fell in with an enormous Calamary between Madeira and Teneriffe. Vigorous efforts were made to secure this monster, but, after a severe struggle, it succeeded in making its escape, leaving its tail behind. Its length was estimated at about fifteen or eighteen feet, and its eight arms, covered with suckers, appeared to be about five or six feet long.

A gigantic Cuttle-fish "was found floating on the surface at the Grand Bank, Newfoundland, in October, 1871, by Captain Campbell, of the schooner *B. D. Hoskins*, of Gloucester, Mass. Dr. A. S. Packard published some account of it in the 'American Naturalist,' 1873, Vol. vii., p. 91. Its jaws were sent to the Smithsonian Institution. Professor Steenstrup, who saw a photograph of them, thought they belonged to *Architeuthis monachus*, an inhabitant of the Northern coast of Europe. The horny jaw, or beak, of this specimen is thick and strong, nearly black; it is acute at the apex, with a decided notch or angle on the inside, about $\frac{7}{8}$ of an inch from the point, and beyond the notch is a large, prominent, angular lobe. The body of the specimen from which this jaw was taken is stated to have measured fifteen feet in length and four feet eight inches in circumference. The arms were mutilated, but the portions remaining were estimated to be nine or ten feet long and twenty-two inches in circumference, two being shorter than the rest. It was estimated to weigh 2,000 lbs."

"Two fishermen were plying their vocation off Great Belle Island, Conception Bay, October 26, 1873. Suddenly they discovered at a short distance from them a dark shapeless mass floating on the surface of the water. Concluding that it was probably part of the cargo of some wrecked vessel, they approached it, anticipating a valuable prize, and one of them struck the object with his boat-hook. Upon receiving the shock the dark heap became suddenly animated, and, spreading out, discovered a head, with a pair of large, prominent, staring eyes, which seemed to gleam with intense ferocity, the creature at the same time exposing to view and opening its parrot-like beak with an apparently hostile and malignant purpose. The men were petrified with terror, and for a moment so fascinated by the horrible sight as to be powerless to stir. Before they had time to recover their presence of mind the monster, now but a few feet from the boat, suddenly shot out from around its head several long, fleshy arms, grappling with them for the boat, and seeking to envelop it in their folds. Only the two longest of these arms reached the craft, and, owing to their great length, went completely over and beyond it. Seizing his hatchet, with a desperate effort one of the men succeeded in severing these limbs with a single well-delivered blow, and the creature, finding itself worsted, immediately disappeared beneath the waters, leaving in the boat its amputated members as a trophy of the encounter. One of the arms was unfortunately destroyed before its value was known, but the other, when brought to St. John's, and examined by the Rev. M. Harvey, was found to measure no less than nineteen feet; and the fisherman who acted as surgeon declares there must have been at least six feet more of this arm left attached to the monster's body."†

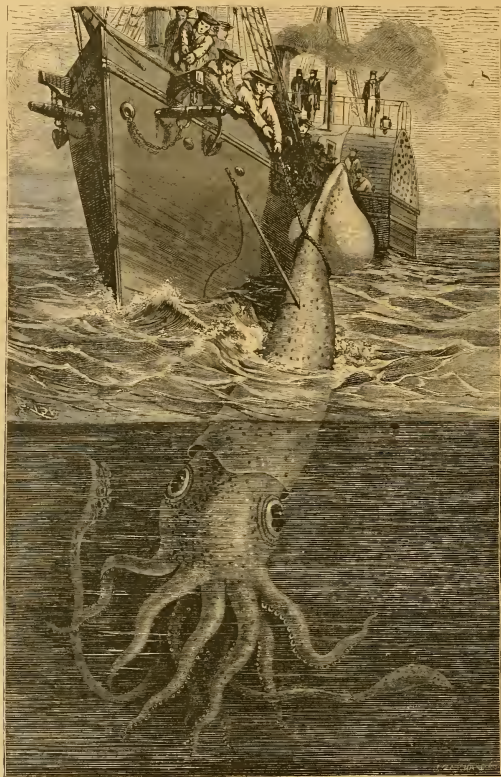
Professor Verrill writes:—"This fragment, which is preserved in the Museum of St. John's, Newfoundland, represents the distal half of one of the long tentacular arms, with its expanded terminal portion covered with suckers, twenty-four of which are larger than the rest; they are in two rows; the border is not serrated. They measure 1.25 inch in diameter; the other suckers are smaller, very numerous; the edge of each is supported by a serrated chitinous ring. The part of the arm preserved measured nineteen feet in length, and 3.5 inches in circumference, but wider, 'like an oar,' and six inches in circumference near the end where the suckers are situated; but its length, when entire, was estimated at forty-two feet."‡ Professor A. E. Verrill estimates the entire length of the creature, including its arms, to have been sixty feet. The fishermen told Mr. Harvey that when wounded the Calamary ejected such a vast quantity of ink that the water was discoloured for some 200 square yards around.

* *Zoologist*, June, 1875.

† W. S. Kent, *Proceedings of the Zoological Society*, 1874, p. 178.

‡ "Silliman's American Journal," 1875, vol. ix., p. 178.

“A specimen was found alive in shallow water at Coomb's Cove, and captured.” Professor A. E. Verrill says of this:—“It is stated that its body measured ten feet in length, and was ‘nearly as large round as a hogshead’ (ten to twelve feet); its two long tentacless (of which only



GIGANTIC CUTTLE-FISH HOOKED BY THE FRENCH STEAMER "ALECTON" OFF TENERIFFE.

one remained) were forty-two feet in length, and ‘as large as a man's wrist.’ Its short arms were six feet in length, by about nine inches in diameter, ‘very strong and stout.’ The suckers had each a serrated edge. The colour was reddish. The loss of one long arm, and the correspondence of the other in size to the one amputated from the preceding Cuttle-fish, justifies

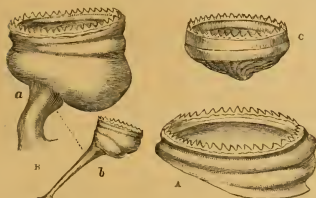
a suspicion that this was actually the same individual that attacked the boat. But if not, it was probably one of the same species, and of about the same size."

A pair of jaws and two suckers were sent to the Smithsonian Institute by Rev. A. Munn. They were taken from a Cuttle cast ashore at Bonavista Bay. He states that it measured thirty-two feet in length and six feet in circumference. Professor Verrill thinks this is probably the entire length, including more or less of the arms. The jaw is large and broad, but thinner than that found by Captain Campbell, and without the deep notch and angular lobe seen in that specimen. It probably belongs to the *Architeuthis dux* of Steenstrup.

On January 31, 1874, the Rev. M. Harvey described parts of a giant Calamary, taken near St. John's, Newfoundland, of which the subjoined is a note:—"A few days ago three of our fishermen residing in Logie Bay, three miles from St. John's, were overhauling a herring-net, when they found entangled in its folds a huge Calamary. "With great difficulty they succeeded in despatching it and bringing it on shore, being compelled to cut off its head before they could drag it into their boat. Having purchased it of the fishermen, I have carefully examined and measured it, and have had the head and surrounding arms photo-



UPPER (A) AND LOWER (B) JAW OR MANDIBLE OF
ARCHITEUTHIS MONACHUS. (Steenstrup.)
(Reduced to one third nat. size.)



A, MARGINAL RING OF SUCKER FROM ONE OF THE SESSILE
ARMS OF *ARCHITEUTHIS MONACHUS* (enlarged two diameters);
B, LARGE (a) AND SMALL (b) SUCKER FROM THE TEN-
TACULAR ARMS OF SAME (nat. size); C, LARGER SUCKER
FROM TENTACLE OF SAME (nat. size).

graphed, as well as the body, both being at present preserved in brine. The body is eight feet in length and five in circumference. The arms, ten in number, radiate from the top of the head. The mouth of the creature consists of a strong horny beak, exactly like that of a parrot in shape, and about the size of a man's fist. The eyes are placed on each side of the head from which the arms extend, and are large, dark, and prominent, the membranous sockets being four inches and a half in diameter. The two longest arms measure each twenty-four feet in length, are only three inches in circumference, and are very tough and strong, and at the extremity are covered with powerful suckers, the largest being one inch and a quarter in diameter, the smallest not larger than a split pea. There are about eighty suckers on each arm, which tapers to a

pretty fine point. Each of the eight short arms is six feet in length, and at the point of junction with the head is nine inches in circumference. They taper to a point, and on the under side are entirely covered with a double row of powerful suckers one inch and a quarter in diameter, each having a sharp denticulated edge and a membrane in the centre, which the creature can retract at pleasure, and thus create a vacuum. Each of these short arms has nearly one hundred suckers, and the moment one of them touches its prey it feels the contact, and draws back the membranous piston; a vacuum is created, and the edges of the disc are pressed against the surface of the victim, with a force equal to the weight of the atmosphere added to the weight of water which is above it. The more the victim writhes it comes in contact with more and more discs in succession, each of which adheres, and other arms soon encircle it, and bring it within reach of the powerful beak. No fate could be more horrible than to be entwined in the embrace of those eight clammy, corpse-like arms, and to feel their folds creeping and gliding around you, and the eight hundred discs, with their cold adhesive touch, glueing themselves to you with a grasp which nothing could relax, and feeling like so many mouths devouring you at the same time. Slowly the horrible arms, supple as leather, strong as steel, and cold as death, draw their prey under the horrible beak, and press it against the glutinous mass which forms the body. The cold, slimy grasp paralyses the victim with terror, and the powerful mandibles rend and devour.

"No Cuttle of such dimensions as the one I am describing has ever before been captured. If its

arms were extended they would be forty-eight feet between their extremities, while two of the shorter arms would measure thirteen feet from tip to tip. This specimen, although large, is but an infant compared to some which have been seen around these shores. The Rev. Mr. Gabriel assures me that in 1870 two Cuttles were cast ashore at Lamlaine, their bodies measuring respectively forty and forty-seven feet. Another gentleman here, whose testimony is thoroughly trustworthy, tells me he measured the body of one which came ashore two years ago, and found it was eighty feet in length. Never until now were Cuttles of such colossal dimensions seen in cold latitudes.*

Four genera of ten-armed Calamaries have been described, founded on the fossil remains of their shells met with in the Liassic and Oolitic formations. They comprise a dilated and spatulate form of fossil pen, named *Teudopsis* by Deslongchamps, of which five fossil species have been described, from the Lias of France and Germany. The genus *Beloteuthis*, of Münster, has a horny lanceolate pen, with a very broad shaft pointed at each end, and with small lateral wings. Of this genus six species have been described, due probably to differences in age and sex. They are found in the Lias of Würtemberg.

The genus *Geoteuthis* (Münster) has a broad pen, pointed behind; the shaft is wide and truncated in front, the lateral wings are shorter than the shaft. Nine species of this extinct genus of Calamaries have been established on their fossil remains from the Lias of Würtemberg, Normandy, and Lyme Regis, whilst several undescribed species occur in the Oxford Clay of Chippenham, Wilts.

Besides the pens of this Calamary, the ink-bag, the muscular mantle, and the bases of the arms are preserved in the Oxford Clay. Some of the ink-bags found in the Lias of Lyme Regis are nearly a foot in length, and are invested with a brilliant nacreous layer. They must have belonged to Calamaries of gigantic size. It is difficult to understand how these ink-bags were preserved full, as the recent Calamaries "spill their ink" on the slightest alarm. (Buckland.)

"It is an oft-told anecdote that the late Dr. Buckland gave some of this fossil ink to Sir Francis Chantrey, who pronounced it to be of unusually good quality, and with it made a drawing of the specimen from which it was taken. This drawing was afterwards in the possession of the late Frank Buckland. I have also seen a cake of fossil sepia—prepared by Messrs. Newman for Professor Dick, of Cambridge, about the year 1850—which rubs as smoothly and is as rich in colour as that manufactured from the ink of recent Cuttle-fishes." (Henry Lee.)

Another fossil form is the genus *Leptoteuthis* of Von Meyer, from the Lithographic stone of Solenhofen. The pen of this species is very broad, rounded in front, pointed behind, with obscure diverging ribs. The beaks of some fossil forms are known, and also the hooklets of the arms of probably a clawed form of Calamary from the Lias of Dorsetshire. Specimens of many of these may be seen in the British Museum of Natural History. Wagner's genus, *Acanthoteuthis*, from the Lithographic stone of Solenhofen, is founded on the fossil hooks of a Calamary. These show that the animal had ten nearly equal arms, all furnished with a double series of horny claws throughout their entire length.

FAMILY IV.—BELEMNITIDÆ.

As there is no living representative of this family, we are obliged to base our description entirely on its fossil remains. The fossil shells of this singular Cephalopod have long been known. Probably few forms of extinct animal life have received more attention than the Belemnites and its allies, a group peculiar to the Secondary rocks.

The earliest notices of this fossil date back to 1553, but their chief historians have been Dr. Buckland (1829-36), Owen (1844), Woodward (1851-6), and Huxley (1864).

The part to which the name "Belemnite" is applied consists of the well-known sub-cylindrical calcareous fossil, called by the quarrymen and peasants "Thunderbolts," "St. Peter's Fingers," &c. It is, in fact, only the "guard," or "rostrum," of the internal shell of a species of Squid, or Cuttle, the lower end of which is more or less pointed and the upper is hollowed out, with a conical cavity called the *alveolus*.† Into this cavity is inserted a series of conical *septa*, or partitions, which, when fossilised by the infiltration of carbonate of lime, leave behind a number of "meniscus-shaped" casts of the chambers which present the appearance of a series of graduated watch-glasses,

* "Annals and Mag. Nat. Hist.," 4th series, vol. xiii., p. 68.

† From *belemnion*, Gr., a dart.

‡ Lat., *alveolus*, a channel.

piled loosely upon one another. The upper portion of this chambered division of the shell of the Belemnite is enclosed in a thin shell-wall.* The chambers themselves, and septa which divide them, are traversed vertically on one side by a minute pearly tube, called the "siphuncle." The chambered portion is called the "phragmacone."† Rising above the "conothea," a thin shelly substance is sometimes found. This, which is called by Huxley the "pro-ostracum," is believed to be the homologue of a portion of the pen of the Cuttle-fish.

In addition to this, we now know certainly that the Belemnite possessed an ink-bag, and that its arms were provided with suckers and hooks, and that it had, like its congeners, a horny beak.

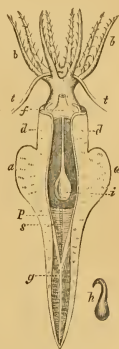
Long before Professor Huxley had described (in 1864) a nearly perfect Belemnite from the Lias of Lyme Regis, having all its parts associated together, there had been obtained from the Oxford Clay of Chippenham, by Mr. W. Cunningham, F.G.S., specimens of *Belemniteuthis*, showing the guard, the phragmacone, the conothea, the ink-bag, the funnel, the outlines of the fins and *poda*, with the eyes, acetabula, or suckers, and horny hooks. The feet and tentacles in this old fossil genus were of nearly equal length, and furnished with a double alternating series of horny hooks, from twenty to forty pairs on each foot; the fins were large and placed on the centre of each side.

More than one hundred species of Belemnites have been found in a fossil state, ranging from the Lias to the Chalk, and distributed over the whole of Europe. A few species have been found in the Chalk of Southern India, in the Jurassic formation of the Himalayas, and in New Zealand. The guard, which is most commonly the only part preserved, is very variable in its proportions, being sometimes only half an inch longer than the phragmacone, at others one or even two feet in length. The genera belonging to this family are:—Firstly, *Belemnites* (already referred to); secondly, *Belemnitella*, of which six species are described from the Chalk and Greensand formations; thirdly, *Xiphoteuthis*, a curious genus with a single species from the Lias of Lyme Regis; fourthly, *Belemniteuthis* (of Miller and Pearce, 1842), from the Oxford Clay; fifthly, *Conoteuthis* (of D'Orbigny), from the Greensand of France and England, a form which connects the ordinary Calamaries with the Belemnites.

FAMILY V.—SEPIADÆ.

Sepia officinalis, the common Cuttle-fish, is one of the most beautiful and curious of British molluscs; but although its "bone," or shell, is frequently cast up on all the sandy shores, the creature itself is rarely seen and seldom taken. Its body is flattened from back to front, and correspondingly broad laterally. It is rounded below and truncated above, giving to its outline the form of an escutcheon. All around the margin run narrow and delicate fins, one on each side, of equal breadth, except at the extremity, where they meet, and present, as it were, a notched termination to the body. The back is smooth or slightly tuberculated. The head is much narrower than the body, although in itself broad; in the region of the eyes it is very prominent, and crowned above with eight rather short, stout, lanceolate, slightly keeled feet. On their inner sides are four rows of equal and regular, but rather small, suckers, which are globular and stalked, and have simple horny hoops. The margins of the feet are fringed by a membrane, and the fourth pair are crested. The tentacula are very long, borne upon stout smooth peduncles, terminating in clubs, crested on their backs, and bearing on their flat surface, which is expanded at the sides into a plaited founce, several rows of unequal suckers, of which the central are large and few and the terminal ones numerous and minute. The buccal membrane is attached to the arms by web-like processes.

The colours of this animal resemble the pattern of a Zebra's hide. Centrally, the back is marked by numerous fine, interrupted, irregular bands of white on a dark brown ground; laterally, with



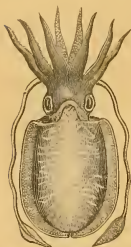
BELEMNITE RESTORED.
(From the "London Geological Journal.")

b, the Eight Arms furnished with Horny Hooks; c, Beak; d, siphuncle; e, phragmacone; f, conothea; g, position of Extinct Branchial Orifice; h, d, siphuncle covered by Mantle; a, a, Fins; i, Ink-bag; p, Phragmacone; s, Siphuncle; z, Solid Fibrous Guard or "Belemnite."

* Called by Huxley the *Conothea*; from *conos*, Gr., a cone, and *thea*, Gr., a sheath, an envelope, a covering.

† *Phragma*, Gr., a septum, a partition.

broad white stripes, many of which, usually alternate ones, bifurcate at each end, the interspaces being rich vandyke-brown; between them and the lateral fin the skin is tinged with tawny and irregularly spotted. The fins themselves are brownish above, minutely speckled with white; a white line runs parallel with the edge, which is itself bounded by a minutely speckled, very narrow border. The neck is white, with greenish and rosy reflections. The back of the head and arms are rich brown,



COMMON CUTTLE.

becoming faint and passing into specks on the sides of the latter. The eyes are black. The tentacular arms are white, with a few pinkish-brown dots. The entire under surface is bluish-white, with rosy specks. No figure that we have seen gives a true idea of the rich painting of the common Cuttle-fish. The female is wider than the male. The "bone," or shell, is thick, but depressed to an ovate-oblong form, varying a little in shape in different examples; it is very regular and symmetrical, smooth and corneous at the sides, and more or less furrowed and rugose over the greater part of its surface. Near the posterior extremity is seen the hard mucro. It is most prominent in young specimens. The under surface is convex, depressed and hollowed out at the sides behind. The margin projects widely below, and curves upwards and inwards, and expands in a wing-like form below around the nucleus of the shell. The substance of the "cuttle-bone" is composed of numerous shelly laminae, separated from each other by a perpendicularly fibrous calcified tissue, exhibiting a shiny white and satiny lustre, and having a puniceous aspect and feel. Thus extreme lightness, in proportion to its bulk, is given to this body.

The bone equals the body in length, without the fins. A full-grown Cuttle-fish measures ten inches in length. The breadth of the body is six inches. The arms are five inches in length, and the tentacles a foot and a half long.

This animal seems to be generally distributed around the shores of Britain. It is scarce to the north of the island, more common to the south, and exceedingly abundant in the Mediterranean. The eggs are dark, oval-shaped, with prominent summits, and have a membranous ring at their bases, by which they are attached to sea-weed, or fixed to each other so as to form masses of considerable numbers.*

Although, as already seen, we are no longer studying animals belonging to the vertebrate classes, but to the invertebrata, nevertheless we find, besides the internal shell of the Cephalopoda, that the principal nerve-mass, or "supra-oesophageal ganglion" (so called because it is placed *above* and around the gullet, or oesophagus), is protected by a thick cartilage, which extends in different directions, so as to afford a basis of attachment to the chief muscles of the body, thus serving in lieu of an internal skeleton. It is most largely developed in the Dibranchiate division, and especially so in the Cuttle-fish. In the Cuttle the cranial cartilage completely surrounds the gullet, and expands above into a cavity to protect the brain, is hollowed below into cavities to form organs of hearing, and at the sides to give support to the back part of the orbits. The long lateral fins are each supported by a narrow flattened plate of cartilage, to which the powerful fin-muscles are attached by fibro-cartilaginous laminae, resembling those which support the fins of the cartilaginous fishes, such as the Ray. (Owen.) There is a strong muscular heart in all the animals belonging to this class, which, when single, is always systemic. Besides the aortic or systemic heart, which has only one cavity or ventricle, each vessel leading to the gills has a dilated contractile portion, which dilatations may be considered as branchial hearts, so that there are three separate contractile portions of the circulatory system.

"The common Cuttle-fish, often called by sailors the 'Scuttle,' when seen alive, is a lovely object. Unlike the skulking, hiding Octopus, but equally rapacious, it loves the daylight and the freedom of the open sea. Its predatory acts are not those of a concealed and ambushed brigand lying in wait behind a rock, or peeping furtively from within the gloomy shadow of a cave, but it may better be compared to the warlike Comanche vedette, seated motionless on his horse, and scanning from some elevated knoll a wide expanse of prairie, in readiness to swoop upon a weak

* Forbes and Hanley: "British Mollusca."

or unarmed foe. Poised near the surface of the water, like a hawk in the air, the *Sepia* moves gently to and fro in its tank by graceful undulations of its lateral fins, an exquisite play of colour occasionally taking place over its beautifully barred and mottled back. When thus tranquil, its eight pedal arms are usually brought close together, and droop in front of its head, like the trunk of an elephant shortened, its two longer tentacular arms being coiled up within the others and unseen. Only when some small fish is given to it as food is its facility of rapid motion displayed. Then, quickly as a Kingfisher darts upon a Minnow, it pounces on its prey, enfolds it in its fatal embrace, and retires to a recess of its abode to tear it piecemeal with its horny beak, and rend it into minutest shreds with its jagged tongue. In shallow water, however, it will often rest for hours on the bottom, after a hearty meal, looking much like a sleepy Tortoise. The Cuttle-fishes are so voracious that fishermen regard them as unwelcome visitors. Some localities on our own coast are occasionally so infested by them that the drift netting has to be abandoned, in consequence of their devouring the fish, or rendering them unsalable by tearing them with their beaks as they hang in the meshes.

"The *Sepia* seldom lives long in confinement. Although, like the Calamaries, it often swims gently forward by the use of its fins, its usual mode of rapid progress is the same as that of the Octopus, namely, darting backwards by the ejection of a stream of water through the funnel. In a limited space like an aquarium tank there is not sufficient room for its rocket-like rush, and therefore its hinder extremity so frequently comes in contact with the rockwork that the skin is worn through until the edge of the internal shell, or 'sepiostaire,' is visible, and death follows. The animal cannot see behind it, and so it often happens that it similarly comes to grief in its natural habitat, especially in calm weather, when, as Professor Edward Forbes says, 'not a ripple breaks upon the pebbles to warn it that the shore is near. An enemy appears; the creature ejects its ink, like a sharpshooter discharging his rifle ere he retreats, and then, darting away tail foremost, under cover of the cloud, grounds itself high upon the beach, and perishes there.'"^{*}

It is somewhat remarkable that whilst the Octopus shuns the light, and retreats from that of the lantern, the Cuttle and Squid are attracted by it. At Trincomalee, at certain seasons of the year, the bay is illuminated during the night by hundreds of lights of fishing-boats moving hither and thither. A dead Cuttle is generally the bait used. This is suspended in the water, and when hauled in from time to time one or more of its species are found fast to it, and feeding on their deceased relative. When removed from the water they emit a peculiar "squelching" noise, which has been compared to the grunting of a hog. It is caused by the forcing of air instead of water through the siphon tube.

"John Hotton (a fisherman of Polperro) says, that some time since he was at sea for the purpose of catching Cuttles, when the night was so dark that, though Cuttles were in plenty, and followed the bait to the surface, he could not see to hook them. He then desired his son to take a lantern, and hold it close to the water, so that he might see, when, to his surprise, a great many Cuttles gathered round the light, and without bait or hook he caught eighteen by hooking them with the rod (gaff). Since then he has more than once put the same plan in practice."[†]

The crystalline lens of the eye, which is soft in quadrupeds and cartilaginous in fishes, is very solid in the Cephalopoda. It is almost calcareous, and very peculiar in form. It consists of two double concave portions, divided by a deep groove, in which are inserted the ciliary processes. The two halves, which are almost globose at their outer surfaces, separate easily, and exhibit internally a series of concentric coats, which reflect with a beautiful nacreous opalescence and play of colours. In some parts of Italy, as in Genoa, the women on festival days use these lenses as beads for necklaces. They were also used as ornaments by the ancient Peruvians, and several of a large size, which were found in the tombs, and in the eyes of mummies from Peru, are preserved in the Christy



BRANCHIA AND HEARTS OF
COMMON CUTTLE.

a, Aorta; *v*, Vena cava; *f*, Visceral veins; *g*, Systemic heart; *h*, Ducts of branchial veins; *c*, *d*, Branchial hearts; *b*, *e*, Branchial organs.

^{*} Henry Lee: "Aquarium Notes."

[†] From Jonathan Crouch's MS. "Diary," dated 1819.

collection, British Museum. Mr. Stutchbury mentions that the Sandwich Islanders sold these lustrous eyes to the Russians as pearls.

A remarkable organ with which some of the Cephalopoda are provided is a sac, popularly called the "ink-bag," in which is stored a deep black secretion, which they are able to employ at will as a protection from rapacious enemies. On the approach of a suspected foe the animal discharges a quantity of this dense fluid, which renders turbid the surrounding water, and thus enables its owner to escape in the obscurity. There is a communication between this ink-bag and the funnel or locomotor-tube, so characteristic of all the Cephalopoda, so that when the ink is ejected it is forcibly emitted with the stream of water, which produces the rocket-like backward motion. The very effort to escape thus serves the double purpose of propelling the creature away from the danger and discolouring the water through which it moves.

"The position of the ink-bag varies in different families. In the Octopods it is buried in the substance of the liver, and this animal does not emit its ink so readily as the Cuttle or the Squid. They very rarely do so in captivity, except when greatly exhausted or persistently irritated. It has



SEPIA ELEGANS.

been said that after being a few hours in captivity the Octopus loses the power of secreting ink. There is no foundation at all for such a statement. When placed in a tank especially reserved for it, in which are no enemies to cause it fear, it has no need to conceal itself, and therefore does not unnecessarily eject its cloudy fluid." Mr. Lee states, "I have never dissected an Octopus, no matter how long it might have lived in confinement, without finding the ink-bag fairly charged, though some of its contents are sometimes emitted when the animal is at the point of death."

"The Cuttle (*Sepia*) discharges its ink on the slightest provocation; and this is sometimes very troublesome and annoying when this species is exhibited in an aquarium. The quantity of water its ink will obscure is really surprising. The fluid is secreted with amazing rapidity, and the black ejection frequently occurs several times in succession. I have (says Mr. Lee) often seen a Cuttle completely spoil in a few seconds all the water in a tank containing 1,000 gallons."

When first taken, the *Sepia* is most sensitively timid. Its keen, unwinking eye watches for and perceives the slightest movement of its captor, and if even most cautiously looked at from above, its ink is belched forth in eddying volumes, rolling over and over like the smoke which follows the discharge of a great gun from a ship's port, and mixes with marvellous rapidity with the water, whilst the animal simultaneously recedes to the best shelter it can find.

It is worthy of notice that the Pearly Nautilus and the allied fossil forms are without this means of concealment, which their strong external shell renders unnecessary for their protection.

"Fishermen are well acquainted with the fact that the Cephalopods—at any rate, our British representatives of the *Sepiidae*, *Calamaries*, and *Octopoda*—habitually discharge, when taken, a jet of black water, and the two former sometimes eject their ink in the faces of their captors. It has been regarded as doubtful whether this is an intentional act or whether it is accidental, and consequent on the bringing of the orifice of the siphon-tube above the surface, and the removal of the resistance to the outpouring current which, when ejected under water, would in the one case have been a means of locomotion, and in the other of concealment of their whereabouts. Some have supposed that the emission is involuntary, and is produced much in the same way as the water is tossed up in spray by the screw of a steam-vessel when her stern rises whilst she is pitching heavily in a rough sea. Others who have experienced the effect of this habit of the animal's have persistently asserted that they take deliberate aim, with the motive of aggression or self-defence.

"The 'ink' which the Cuttle-fish has the power of ejecting when alarmed for the purpose of obscuring the water and hiding its own retreat was formerly used in writing. Cicero mentions this use of it, and from it also is made the true 'sepia' of artists. I have more than once lately seen it stated that the ink of the Cuttle-fish is no longer employed for this purpose, and that 'sepia' is now

prepared from lamp-black. A great deal of rubbish of this kind is probably sold; but I have recently seen at Messrs. Newman's, the well-known artists' colourmen, in Soho Square, thousands of ink-bags of Cuttles in the raw state ready to be manufactured into 'sepia.' The fishermen of some of our southern counties, when cleaning Cuttles and Squids for bait, habitually dry the ink-bags and their contents, and preserve them till Messrs. Newman's agent visits the district and collects them. If the Newfoundland fishermen, when 'Squid-jigging,' would take the trouble to preserve the ink-bags, they would find a ready sale for them, and might make of them a profitable perquisite. The beautiful drawings with which Cuvier illustrated his 'Anatomy of the Mollusca' were executed with the ink which he had collected whilst dissecting many specimens of Cephalopoda; and it is well known that fossil Cuttle-fishes have been found with the ink-bag perfect, and that from its contents excellent 'sepia' has been obtained." (Henry Lee.)

"The eggs of the various families of Cephalopods differ greatly from each other. Those of the Cuttle (*Sepia*) are like black grapes, each having a flexible stalk, looking and feeling like india-rubber. The mother takes a turn with this stalk round the stem of the twig or seaweed to which she wishes to attach the egg; the india-rubber-like material is soft and sticky when first laid, and so, instead of splicing the loop, she brings the end round to the base of the stalk, close to the egg, and cements or welds it there into a solid ring. Thus the eggs are attached one by one. Sometimes the stalk of one is fastened round that of another, and occasionally the process is repeated until the whole mass is made up in this way, without any central stem. The work is as well and neatly done as if skilled hands had been employed on it, but how the mother Cuttle-fish effects it I believe no one knows. I hope we may some day have opportunities of watching her.

"Aristotle wrote that the *Sepia* fastens her eggs near land upon seaweeds, reeds, and other bodies which may be found on the shore, and even around sticks and faggots placed there for the purpose of entrapping her. 'She does not lay them all at once,' he says, 'but at several intervals, the operation lasting fifteen days; and after the oviposit is completed she sheds her ink upon them, which turns them from white to black, and causes them to increase in bulk.' He also avers that she hatches them in the place where she has deposited them, and is often to be seen with her body resting on the ground and covering them. I do not think that the dark hue of the membranous integuments of the eggs, and of their pedicle, or foot-stalk, is in any way attributable to their being stained by the animal's inky secretion, although I have frequently seen masses of these eggs, the integuments of which were not black, but perfectly colourless and pellucid. That the mother broods over them, and protects them till they are hatched, is quite in accordance with the observed habits of the Octopus, and is therefore not improbable. But, as with the Octopus, I am satisfied that no incubation takes place.

"At intervals, for many years past, I have found the eggs of the *Sepia* and *Loligo* in early stages of their development, and have hatched them out, without any assistance from their parent, by merely suspending them in sea-water in a tank or tub, and changing the water frequently. The same also has been frequently done in the Brighton Aquarium. This having been proved and demonstrated by actual experiment, it is unnecessary to fortify facts by reasoning. But I have seen a branch of a tree or shrub, measuring more than two feet in height from the base of the broken stem to the upper part of its branches, and fourteen inches from side to side across the tips of the twigs, covered with the eggs of *Sepia* in single rows along them. I cannot, of course, be certain that these were all laid by one female, but it is evident that one could not cover so great an area continuously as an incubator, and that, if it were possible, she would subject herself to unnecessary toil in so doing, seeing that they were all hatched in a tank, after having been for about ten days deprived of maternal care.

"The young *Sepia*, when born, is much larger than a baby Octopus or Squid. It is of about the size of a rather small horse-bean. When about half developed, the little animal has the head and eyes disproportionately large, but gradually acquires a greater resemblance to its parent. If the black integument be removed, as one would skin a grape, it may be seen moving in the fluid which fills the egg. Cut down to the little living grape-stone under water, and away it will swim, with all its wits about it, and in possession of all its faculties, with as much facility and self-possession as if it had considerable knowledge of the world. It sees and avoids every obstacle, and if you take it out of the water in your hand, the precocious little creature, not a minute old, and not sufficiently matured to leave the egg naturally, will spurt its ink all over your fingers. You may tame an old Cuttle-fish,

and it will learn to know you are a friend; but the youngsters are as shy as human babies, and regard every one but their mother as an enemy."*

The preference for the light, described by Mr. Henry Lee, as exhibited by the young Octopus, appears to be common also to the young Squid and Cuttle-fish. The latter generally seek the surface of the water ;

sometimes swimming gently by means of the locomotor-tube and the undulating movement of the marginal fins, and at others poising their bodies motionless, as if basking. The habit in these two families is not so surprising as it is in the Octopus, because the adult Sepia and Loligo are not cave-dwellers, but frequent the open sea, and often approach the surface.

The internal shell (*sepiostaire*), incorrectly called the "cuttle-bone" of the Sepia (sometimes also called "sea-biscuit," from its shape, and its being frequently found floating on the surface of the water), is used, when pounded, as polishing powder by jewellers, and, under the name of "pounce," to smooth writing-paper where an erasure has been made with a



EGGS OF THE COMMON CUTTLE-FISH.

penknife. Known as "white coral powder," it used to be regarded as the very best dentifrice, and was formerly prescribed in medicine as an antacid and absorbent.

The Roman ladies employed it, burned and pulverised, as a cosmetic for the face; and it was, no doubt, a good substitute for the "pearl powder" now in fashion. Broken pieces of it are also occasionally placed between the wires of the cages of song-birds for them to peck at, instead of chalk or other calcareous substances.

Ten species of Sepia have been established on the fossil remains of "Cuttle-bones" from the Solenhofen limestone. Some of these sepiostaires, or "bones," attained a length of two feet.

Several species have also been founded on the *muco* (or sharp point or extremity) of fossil shells of Sepia, found in the Eocene Tertiary formation of the London and Paris basins. One species (*Sepia unguis*) occurs fossil in Texas.

Referring to the use of these animals by the Greeks as an article of food, Professor Edward Forbes writes:—"The traveller who, when treading the shores of the coasts and islands of the Egean, observes—as he can scarcely fail to do—the innumerable remains of the hard parts of Cuttle-fishes piled literally in heaps along the sands, or, when watching the Greek fishermen draw their nets, marks the number of these creatures mixed up with the abundance of true fishes taken and equally prized as articles of food by the captors, can at once understand why the naturalists of ancient Greece should have treated so fully of the history of the Cephalopoda, and its poets have made allusions to them as familiar objects. One of the most striking spectacles at night on the coasts of the Egean is to see the numerous torches glancing along the shores, and reflected by the still and clear sea, borne by poor fishermen paddling as silently as possible over the rocky shallows



INTERNAL SHELL OF THE SEPIA.

* Henry Lee : "Aquarium Notes."

in search of the Cuttle-fish, which, when seen lying beneath the waters in wait for its prey, they dexterously spear, ere the creature has time to dart with the rapidity of an arrow from the weapon about to transfix his soft but firm body. As in ancient times, these molluscs constitute now a valuable part of the food of the poor, by whom they are chiefly used. We can ourselves bear testimony to their excellence. When well beaten, to render the flesh tender, before being dressed, and then cut up into morsels and served in a savoury brown stew, they make a dish by no means to be despised, excellent both in substance and flavour. A modern Lycian dinner, in which stewed Cuttle-fish formed the first, and roast Porcupine the second course, would scarcely fail to be relished by an unprejudiced epicure in search of novelty."

The bone of the Chinese species attains a length of nearly two feet. The Japanese are large consumers of Cuttle-fish as an article of food.

Upwards of thirty species of Cuttle-fishes have been described. Their distribution is world-wide. Two are recorded as British: the *Sepia officinalis* and the more rare *S. biserialis*, of which only the sepistaire, or internal shell, has been obtained.

FAMILY VI.—SPIRULIDÆ.

Since the publication of "The Zoology of the Voyage of H.M.S. *Samarang*," in 1848, we have until recently learnt but little concerning the owner and constructor of the beautiful pearly-white shell known as *Spirula*, whose many-chambered spiral tests (composed of separate whorls, like a little post-horn) are scattered in thousands on the shores of New Zealand, and a few of which are yearly wafted by the warm current of the Gulf Stream to British and Irish shores, and have been picked up on the coast of Kerry, in Ireland, at Tenby, in South Wales, and on the coast of Cornwall.

The materials which Professor Owen had at his disposal when he prepared his first account, in 1848, consisted of a headless specimen, brought home by Admiral Sir Edward Belcher, with the hinder part of the mantle torn off; part of another specimen of *Spirula*, showing the shell, with the shell attached, taken off Timor; and a very unique specimen of *Spirula australis*, in Mr. Cuming's collection, "perfect in all its parts except the termination of one of its tentacles," found in a fresh state by Mr. Percy Earl on the shore of Port Nicholson, New Zealand. This last specimen Professor Owen was permitted to draw, but was not then allowed to dissect, and it was not until 1878, after an interval of thirty years, that he was enabled to complete his anatomy of this Cuningian rarity.*

This singular little Squid differs in several important points from the other two-gilled and ten-armed division to which it belongs: in the absence of any well-developed fins; also the two lobes of the mantle seem to embrace the shell, all save one tiny portion, which may at times have been slightly exposed by the contraction of the mantle-lobes, though this seems improbable.

The base of the body, which in the Squids ends in a pointed, often arrow-shaped, fin, in *Spirula* terminates in an elliptical convex substance with a central depression (*x*), in the midst of which is a pore terminating blindly. "If," says Professor Owen, "the disc were applied to a flat surface and the central part were withdrawn from the level, a vacuum would be produced, which would convert the disc into a sucker. Should the *Spirula* so attach itself, as Rumphius describes—('the little Post-horn' *Spirula* hangs to the rocks by a thin and small door, or disc, by which it sets itself fast to the rocks)—its tentacles and arms would be free to exercise their prehensile power on any passing object of food. The formal analogy to the Polype, indicated by Aristotle's name for the 'Poulpe,' would thus be carried farther in *Spirula* by its occasional repetition of the status of a hungry Actinia."

This power of attaching itself by means of a terminal suetorial disc—if we may rely on



SECTION OF SPIRULA
AUSTRALIS.†
(After Owen.)

* See "Annals and Mag. Nat. Hist.," January, 1879 (Plates I.—III.).

† Explanation of woodcut of *Spirula*:—A, dorsal wall of shell; B, ventral wall of shell; a, dorsal mandible of beak; t, ventral mandible of beak; c, the eye; f, the funnel or siphon; d, ventral edge of mantle; g, gill or branchia; m, retractor muscles uniting animal to shell; e, chambers of shell laid bare, exposing s, the siphuncle; x, the supposed sucker or disc for adhering to foreign bodies by; b, b, the oral appendages, feet or poda; t, one of the long tentacles.

Rumphius's statement—is peculiar to *Spirula* among Cephalopods; nevertheless it does, no doubt, occasionally float at or near the surface, and swim, after the manner of its kind, by the ejection of water through the funnel from its branchial sac. The animal has also a minute ink-bag, by which, if needful, to conceal its retreat by clouding the water, as in others of its class.

Spirula has the same number of arms (eight) and of tentacles (two) as in other Decapodous Cuttles. The arms are short and provided with minute irregularly-scattered acetabula, or suckers. The beaks are horny and well developed for the size of the animal.

The shell itself offers important points of difference from the other living members of its order, and at the same time connects it in a remarkable manner with the extinct group, the *Belemnitida*, on the one hand, and with the Pearly Nautilus and the Tetrabranchiata, or four-gilled division, on the other. If we compare its shell with that of the Argonaut, which is the only other convoluted internal shell in its own division, we see that the latter has no chambered portion, that it is only a simple "nidamental shell," developed in the female as a receptacle for the ova, and not in any way organically connected with the animal. In *Spirula* it is a complex structure, divided up into chambers, and these each penetrated by a delicate pearly tube, called a "siphuncle." The shell is, moreover, organically united to the animal, serving as the *point d'appui* of the retractor muscles of the funnel and of the head, with its locomotive and prehensile organs.

The shell is, moreover, sinistral (or left-handed), so that its relation to the soft parts of the animal is exactly the reverse of that of Nautilus. Left-handed shells in the Snail and other Gasteropoda are not uncommon, as we shall see presently.

Dr. S. P. Woodward mentions that he had formerly in his cabinet an Argonaut shell with the nucleus reversed, implying that the animal had turned right round in its shell, and then had continued to add to it in the opposite direction. This would be impossible for any mollusc whose shell was organically attached to the body of the animal.

D'Orbigny has described, under the name *Spirulirostra*, an elegant little fossil shell from the Miocene Tertiary beds of Turin, in which the upper part consists of a chambered portion (or "phragmacone") with a siphuncle, coiled into a spiral, the volutions of which are separated. This *Spirula*-like shell is lodged in a pointed calcareous portion, or *rostrum*, corresponding to the guard of the Belemnite. This interesting fossil thus serves as a link between the living *Spirula* and the fossil Belemnites; for if a guard were added to the shell of *Spirula* it would be converted into a form like a *Spirulirostra*.

It seemed as if this little Cephalopod were destined to remain long a great rarity, although so abundant in its ordinary habitat. The late lamented M. Pourtales informed the writer that he was present in 1879 in the Museum of the Jardin des Plantes, Paris, when a sea-captain offered ten specimens of the shells of *Spirula* to the Museum. Being told they were very common, and that it was the animal which was the rarity desired, he replied that he had taken all these ten examples alive in the open sea, with the animal, and had with his own hands cleaned them and removed the animal matter, being ignorant of their value! Doubtless [like the elegant *Euplectella aspergillum*, a single specimen of which was originally sold to the British Museum for £30, and which, when Mr. Moseley visited Abu, in the Philippines (1875), "were a 'drug' in the market, and were brought off to the ship in washing-baskets full, and sold at two shillings a dozen"] these rare little Cephalopods will be met with alive in numbers, and we shall know their complete natural history from fresh and perfect specimens; they may even be watched in our *Aquaria* in the living state, as they probably were by the old Dutch naturalist, Rumphius, in 1704.

The ten-armed section of the Dibranchiate Cephalopods approaches most nearly to the Tetrabranchiate division, not only in the fact of their more numerous feet, and the frequent development of an internal circular series of eight short labial tentacles, but also by several internal characters: as, for example, the single oviduct and detached glands for secreting *nidamentum**; the valve of the funnel;

* The material with which the eggs of the mollusca are cemented together, or enveloped, and which is secreted by the *nidamental* (or "nest-forming") gland (from the Latin *nidus*, a nest). This organ is largely developed in the female of all the Gasteropods and Cephalopods.



SPIRULA
AUSTRALIS.
(After S. P.
Woodward.)

the laminated rudiment of a chambered shell in the Cuttle-fish; and the fully developed chambered and siphunculated shell of the Belemnites and Spirula.

ORDER II.—TETRABRANCHIATA.

FAMILY VII.—NAUTILIADÆ.

The external-shelled Cephalopods (represented at the present day by the "Pearly Nautilus" alone, but in the past by the *Nautilus*, *Ammonite*, *Goniatite*, *Orthoceratite*, and a host of other forms) belong to the Tetrabranchiata, or four-gilled division, and were once as extensively represented in the ancient seas of our globe as the naked or internal-shelled Dibranchiata (two-gilled) division are in the seas of to-day.

With the exception of Spirula, already described (whose pearly shell is internal), Nautilus is the only other siphonated shell now known amongst living Mollusca; the chambered character of the shell, with its siphuncle, appears, therefore, to be a unique molluscan structure, entirely confined to the Cephalopoda.

In Nautilus the inner shell-layer and septa are nacreous (composed of mother-of-pearl), the outer layer porcellanous (like porcelain). So far, then, as the composition of the shell goes, that of Nautilus is the same as in many other Mollusca. Its coloration, which, when seen floating on the surface of the water, "resembled a tortoiseshell cat" (as the sailors remarked), is good evidence of its being an external shell; as is still more the fact that it is, when living, coated with a thin layer of epidermis, or *priostراعum*,* which is not a living membrane, and can only be reproduced around the mouth of the shell, or where it is within reach of the margin of the mantle, which is, in most Mollusca, the true shell-secreting organ.

It is the umbonal † portion of bivalve shells and the spires of univalves which first become eroded and injured; and one object, no doubt, in the formation of septa, or partitions, in all shells is to shut off the damaged and untenantable part of their abodes.

It is almost certain that the true "Pearly Nautilus" (*Nautilus pompilius*), as well as the "Paper Nautilus" (*Argonauta argo*), was known to the father of natural history, Aristotle (B.C. 350), for after describing the Argonaut, he says:—"But the other genus is in a shell, like a Snail; it never quits its shell, but exists after the manner of a Snail, and sometimes outwardly extends its arms."

No other notice of the Nautilus worthy of record occurs until the time of the old Dutch naturalist, Rumphius (1705), who, during his long residence at Amboyna, was enabled to procure specimens and make excellent observations thereon.

The following is a translation ‡ of the account given by this early observer, whose figure of the animal, as seen when taken out of the shell, is probably still (says Mr. Moseley) the best extant:—

"When the living Nautilus floats at the surface of the water it protrudes its head with all the tentacles out, and spreads those out in the water, keeping the hinder part of the curl of the shell all the while above water. On the bottom, however, the animal creeps with the other side uppermost, with the head and tentacles on the bottom, and makes tolerably fast progress. The animal remains mostly at the bottom, creeping sometimes into hoop-nets set for fish, and lobster-pots; but after a storm, when the weather becomes calm, they are to be seen floating in troops on the surface of the water. They are doubtless raised up by the waves caused by the storms. It follows that they keep themselves together in troops on the bottom also. The floating, however, does not last long, for, drawing in all their tentacles, the animals turn their boats over and go down again to the bottom. On the other hand, the empty shells are frequently to be found floating or cast up on the shore, for the defenceless animals, having no operculum, are a prey to Crabs, Sharks, and Crocodiles; and therefore the shells are mostly found with the edges bitten off. Since the animal does not adhere fast to its shell, its enemies can easily drag it out, leaving the empty shell to float.

"The young of this Nautilus, not larger than a Dutch shilling, are of a clean mother-of-pearl colour within and without. The rough shell substance overgrows the mother-of-pearl only after a time, and this overgrowth commences from the foremost part of the boat."

* From *peri*, Gr., upon, and *otراعum*, Gr., a shell: the layer of animal substance, or cuticle (*cutis*, the skin), which covers the outer surface of shells.

† *Umbo, ônis*, Lat., the boss of a shield. ‡ "D'Amboinsche Rarikit kamer door": G. E. Rumphius, Amsterdam (1705).

[Shells in this state are believed to have lost their true coloured shell-layer by the solvent action of the gastric juice of the Dolphin's stomach, from which most, if not all, of the young shells of the Pearly Nautilus are usually obtained by collectors.]

"The Nautilus is found in all the Moluccan Islands, and also around the Thousand Islands off Batavia, in Java, yet mostly only the empty shells are met with, for the animal is seldom found unless it creeps into the lobster-pots. The animal is used for eating, like other 'Sea-cats'; but it is somewhat harder in flesh and more difficult of digestion. The shell is in much greater request for the manufacture of the beautiful drinking vessels so well known in Europe."

Dr. Bennett says that the natives of New Holland dive for *Nautilus macromphalus*, and also take it in fish-falls baited with an *Echinus*, whilst the Fijians trap *Nautilus pompilius* with a "Rock-lobster" for bait.

Mr. Moseley* writes:—"In dredging off Matuku Island, in 320 fathoms, on a coral bottom, some *Phorus*, *Turritelle*, and a few other shells were brought up, as well as numerous specimens of the blind crustacean *Polycheles* and other animals, showing the fauna to be a true deep-water one, and with these a living specimen of the Pearly Nautilus (*Nautilus pompilius*). This was the only specimen obtained during the voyage of the *Challenger* of this animal, so rarely seen in the living condition by any naturalist.

"The animal was very lively, though probably not so lively as it would have been if it had been obtained from a less depth, the sudden change of pressure having, no doubt, very much disarranged its economy. It, however, swam round and round a shallow tub in which it was placed, moving after the manner of all Cephalopods, backwards: that is, with a small portion of the top of the shell just out of the water, as observed by Rumphius. The shell was maintained with its major plane in a vertical position, and its mouth directed upwards.

"The animal seemed unable to sink, and the floating of the shell as described, no doubt, was due to some expansion of gas in the interior, occasioned by diminished pressure. The animal moved backwards slowly by a succession of small jerks, the propelling spouts from the siphon being directed somewhat downwards, so that the shell was rotated a little at each stroke upon its axis, and the slightly greater area of it raised above the surface of the water. Occasionally, when the animal was frightened or touched, it made a sort of dash, by squirting out the water from its siphon with more than usual violence, so as to cause a strong eddy on the surface of the water.

"On either side of the base of the membranous operculum-like headfold, which when the animal is retracted entirely closes the mouth of the shell, the fold of mantle closing the gill-cavity was to be seen rising and falling, with a regular pulsating motion, as the animal in breathing took in the water to be expelled by the siphon. The tentacular-like arms contrast strongly with those of most other Cephalopods, because of their extreme proportional slowness, and also their shortness, though they are not shorter proportionately than those of the living *Sepia*. They are held by the animal, whilst swimming, extended radially from the head, somewhat like the tentacles in a Sea Anemone; but each pair has its definite and different direction, which is constantly maintained. This direction of the many pairs of tentacles at constant but different angles from the head is the most striking feature to be observed in the living Nautilus. Thus one pair of tentacles was held pointing directly downwards. Two other pairs, situated just before and behind the eyes, were held projecting obliquely outwards and forwards and backwards respectively, as if to protect the organs of sight. In a somewhat corresponding manner, the tentacular arms of the common Cuttle-fish, whilst living, are maintained in a marked and definite attitude, as may be observed in any aquarium.

"The very great abundance of the shells of the Pearly Nautilus is most strangely contrasted with the rarity of the animals belonging to them. The circumstance is, no doubt, due to the fact that the animal is mostly an inhabitant of deep water. The shells of *Spirula* similarly occur in countless numbers on tropical beaches, yet the animal has been procured only two or three times. We obtained one specimen during our cruise, which had evidently been vomited from the stomach of a fish. I expect that both Nautilus and *Spirula* might be obtained in some numbers if traps, constructed like lobster-pots and baited, were set in deep water off the coasts where they abound in from 100 to 200 fathoms. Nautilus is occasionally caught, both at Fiji and the New Hebrides, in this manner,

* H. N. Moseley, F.R.S.: "Notes by a Naturalist on H.M.S. *Challenger*," pp. 296-300.

in comparatively shallow water, and the animals were so taken in the time of Rumphius, at the end of the seventeenth century. Traps seem never to have been tried for them in deep water. The fact that the living Nautilus was obtained from 320 fathoms shows that it occurs at great depths. It is probably a mistake to suppose that it ever comes to the surface voluntarily to swim about. It is probably only washed up by storms, when injured perhaps by the waves. The living specimen obtained by us seemed crippled, and unable to dive, no doubt because it had been brought up so suddenly from the depths of the sea."

The shell of the Nautilus is involute or discoidal, and has but few whorls. The siphuncle, instead of being placed near the inner margin of the convolutions, is nearly central. In the recent Nautilus the shell is smooth, but in many fossil species it is corrugated, like the patent iron-roofing so remarkable for its strength and lightness. The umbilicus is small or obsolete in the typical Nautilus, and the whorls enlarge rapidly. In the Palaeozoic species the whorls increase slowly, and are sometimes scarcely in contact. The last closed chamber is frequently shallower in proportion than the rest.

In the recent Nautilus the mandibles are horny, but calcified to a considerable extent; they are surrounded by a circular fleshy lip, external to which are four groups of labial or lip tentacles, twelve or thirteen in each group. They appear to answer to the buccal membrane of the Calamary. Beyond these, on each side of the head, is a double series of arms, or branchial tentacles, thirty-six in number. The dorsal pair are expanded, and unite to form the hood, which closes the aperture of the shell, except for a small space on each side, which is filled by the second pair of arms. The tentacles are lamellated on their inner surface, and are retractile within sheaths, or "digitations," which correspond to the eight ordinary arms of the Cuttle-fishes, their increased numbers being indicative of a lower grade of organisation. Besides these, there are four ocular tentacles, one behind and one in front of each eye. They seem to be instruments of sensation, and resemble the tentacles of *Doris* and *Aplysia*. On the side of each eye is a hollow plicated process. This process bears the external ears. The cavity leads to the auditory capsule, along a passage lined with a glandular membrane. The respiratory funnel is formed by the folding of a very thick muscular lobe, which is prolonged laterally on each side of the head, with its free edge directed backwards into the branchial cavity; behind the hood it is directed forwards, forming a lobe, which lies against the black-stained spire of the shell. Inside the funnel is a valve-like fold. The margin of the mantle is entire, and extends as far as the edge of the shell; its substance is firm and muscular as far back as the line of shell-muscles and horny girdle, beyond which it is thin and transparent. The shell-muscles are united by a narrow tract across the hollow occupied by the involute spire of the shell, and are thus rendered horse-shoe shaped. The siphuncle, according to Owen, is vascular. It opens into a cavity containing the heart (pericardium), and is most probably filled with fluid from that cavity.



INTERIOR OF THE SHELL OF PEARLY NAUTILUS, SHOWING THE LAST CHAMBER TO WHICH THE ANIMAL IS FIXED.

a, Mantle; b, Dorsal Fold; g, Shell-muscle; h, Siphuncle; i, Funnel; j, Hood; k, Tentacles; l, Eye; m, Septa; n, Last Chamber.

With respect to the purpose of the air-chambers, much ingenuity has been exercised in devising an explanation of their assumed hydrostatic function, whereby the Nautilus can rise at will to the surface, or sink on the approach of storms to the quiet recesses of the deep. Unfortunately for such poetical speculations, the Nautilus appears on the surface only when driven up by storms, and its sphere of action seems to be undoubtedly on the bed of the sea, where it creeps like a snail, or perhaps lies in wait for unwary crabs and shell-fish, like some gigantic Sea Anemone, with outspread tentacles. The specimen dissected by Professor Owen had its crop filled with fragments of a small crab, and its mandibles seem well adapted for breaking such shells as those of Crustacea, Echini, and Mollusca.

Mr. Frederick Edwards* says:—"It is obvious, therefore, that the hydrostatic balance would be destroyed if any one of the deserted chambers were so injured as no longer to act as a float."

In Woodward's "Museum of the Mollusca" we find it also stated that "the use of the air

* In his "Monograph of the Eocene Cephalopodous Mollusca" (Palaeontographical Society, 1849, p. 12).

chambers is to render the whole animal and shell of nearly the same specific gravity with the water in which it lives." But no such buoy would be required for a bottom-feeder; indeed, it would prevent it from remaining below. On the contrary, the facts of the case tend to show that, like the "water-Spondylus," the chambers were filled, or partially filled, with sea-water, which must find its way into the chambered portion of the shells, by endosmose, through its pores by the great pressure existing at the depth at which the *Nautilus* is found (200 to 300 fathoms), thus displacing the air in spite of the animal. Even at a depth of from twenty to thirty fathoms the pressure of such a column of water would equal more than six atmospheres—how much more, then, at three hundred fathoms?

Mr. George Bennett, M.R.C.S., F.L.S., through whom Professor Owen obtained the first specimen of the animal of the Pearly *Nautilus* described by him in 1832, states:—"On laying carefully open that portion of the shell which contains the chambers, it was found to contain water, which of course immediately escaped."



EXTERIOR OF THE SHELL OF THE
PEARLY NAUTILUS.

The writer, in 1870, had an opportunity of opening the chambered portion of the shell of a *Nautilus umbilicatus*, which had been preserved, with the animal, in spirits of wine. The last three chambers preceding that occupied by the animal were laid bare for a distance equal to half the circuit of the shell-whorl.

The siphuncle (when the chambers were laid open) was quite entire, and sheathed in a thin nacreous investment, which, however, attains considerable thickness near to each septum.

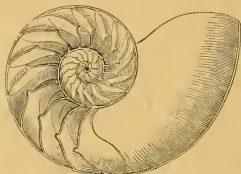
The chambers contained a large quantity of fluid, of which I did not specially take note at the time; but on reading Professor Owen's memoir, I have no doubt that its presence in this, and also in Mr. Bennett's specimen, was not abnormal (as I had supposed), but in accordance with the natural state of all camberated shells, and that it is a misnomer any longer to call them "air-chambers."

Professor Owen writes as follows:—"From the extremity of the sac is continued a small tubular membranous process, which passes through the siphonic apertures in the septa of the shell, and is continued, there is reason to believe, to the innermost chamber. This tube has been surmised to be tendinous or muscular; but the attachment of the shell to the soft parts proves to be effected by much more adequate means. Rumphius appears to have been acquainted with its true structure, for he calls it an artery (*een langen ader*), and, in fact, within the external thin membrane is included a small artery or vein. How far these vessels are continued within the chambered portion of the shell, or in what manner they are distributed, remains for some future investigation; for in the present instance the only part of the shell that was preserved was the small portion adhering to one of the horny tendons, and the membranous tube had been ruptured in removing the animal at a few lines' distance from its origin at the mantle. This tube appears to be contracted at its origin, and its diameter at the wider part is one line and a half."

Even admitting that the purpose of the siphuncle is to maintain the vitality of the shell during the long life of the animal, it seems difficult to imagine how this vitality can be maintained in a non-vascular body. If the siphuncle be a means for repairing the shell, we ought to find some connection between it and the shell, but such does not exist; indeed, the fossil species have in many instances enormously thick pearly or shelly siphuncles.

In fact, when the shell of *Nautilus*, or of any other Mollusc, is once formed, it is extra-vascular, or dead matter, in the same sense that nails and hoofs and hair of higher animals are so, being incapable of repair, save at the growing end, or where in contact with the shell-secreting mantle.

In the specimen of *Nautilus umbilicatus* already referred to, which I had the good fortune to examine, I observed the thin pellicle of membrane, described by Professor Owen, lining the chambers;



SECTION OF THE SHELL OF THE PEARLY
NAUTILUS, SHOWING THE BODY-CHAMBER
AND THE SEPTA GIVING PASSAGE TO THE
SIPHUNCLE.

but as it is only a film, and presents no structure under the microscope, I conclude it to be deposited or left behind by the secreting surface of the mantle when the nacreous septum was formed. And this opinion is strengthened by Dr. Carpenter's statement, "that in every distinct formation of shell-substance there is a single layer of membrane," and "that this membrane was at one time a constituent part of the mantle of the mollusc."

The nacreous covering of the siphuncle was entire, and on removal it was found to enclose a simple membranous tube, composed of an extension of the periostracum, and exhibiting no structure, even under a one-tenth objective.

As I could not detect any artery or vein, I conclude that they probably do not extend beyond the first chamber. This view coincides with Professor Owen's statement that "neither the contents nor the vital properties of the siphon are, however, yet known; an artery and vein are assigned for its life and nutrition, and to extend a low degree of the same influence to the surrounding shell." But the structure of the membranous siphon, in the specimen from which I had the opportunity of examining it in a recent state presents, beyond the first chamber, an inextensible and almost friable texture, unsusceptible of dilatation; it is also coated beyond the extremity of the short testaceous siphon with a thin mother-of-pearl deposit.

We know that the body of the animal in *Nautilus* is attached to the shell by means of the two adductor muscles, and by a continuous horny girdle around the mouth of the body-chamber. The suggestion, therefore, of Von Buch, that the function of the siphuncle was to hold the animal into its shell loses much of its significance. But may it not have been the most important point of attachment between the animal and its shell in the earlier forms of the Tetrabranchiata? In support of this view we may notice that in the fossil Nautili the siphuncle was a shelly tube of considerable size and thickness, whilst in *Orthoceras* it attained to a great magnitude—as, for instance, in the genus *Huronina*, in which it is as large as a human vertebral column. In *Actinoceras*, *Gyroceras*, and *Phragmoceras* the siphuncle is also very large, and contains in its centre a smaller tube, the space between the two being filled up with radiating plates, like the lamelle of a coral.

Speaking of the connection between the *Nautilus pompilius* and its shell, Professor Owen says:—"A third point of attachment is to the bottom of the shell, by the posterior extremity of the mantle, which probably presents a conical form in the embryo Nautilus." If, then, the siphuncle in the young stage forms the main point of attachment between the animal and its shell, we may reasonably argue that the siphuncle in the adult Nautilus is simply the evidence of an aborted embryonal organ, whose function is now fulfilled by the shell-muscles, but which, in the more ancient and straight-shelled representatives of the group (the *Orthoceratites*), was not merely an embryonal, but an important organ in the adult.

The formation of the septa is undoubtedly due to the constant onward growth of the shell season by season, and in the female to the periodic development of the ova within the ovary of the parent, producing, when discharged from the shell, a corresponding reduction in the size of the soft parts of the animal, and necessitating an equal reduction in the space of the body-chamber. In youth these septa represent periods of rest in shell-growth, in middle life periods of fertility, in age reduction of the shell to suit the reduced size of the Mollusc. In this respect the septa in *Nautilus* agree with those found in other Mollusca. "The line of attachment of both the muscles and the cincture progressively advances with the growth of the animal. A certain portion of the fundus of the shell thus becomes vacated, and the Nautilus commences the formation of a new plate for the support of the part of the body which has been withdrawn from the vacated shell. The formation of the plate proceeds from the circumference to the centre, and there meeting the conical process of the mantle, which retains its primitive attachment, the calcification is continued backwards for a short distance around the process which now forms the commencement of the membranous siphon, and requires the partial protection of the calcareous tube. An air-tight chamber is thus formed, traversed by the siphon, which perforates its anterior wall or septum. By a repetition of the same process a second chamber is formed, included within two perforated septa; and similar, but wider, partitions continue to be added concurrently with the formation of the new layers, which extend and expand the mouth of the shell, until the animal

acquires its full growth, which is indicated by the body having receded for a less distance from the penultimate septum before the formation of the last septum is begun." (Owen.)

If we will only bear in mind this fact, that the animal of the Oyster and the Nautilus is compelled by the constant, though almost imperceptible, growth of the mouth or border of the shell to which it is attached by the margin of its mantle to move forward in its habitation, and that its hinge-ligament and shell-muscles are absorbed behind and added to in front, to accommodate themselves to the onward growth of the shell-border, of necessity, therefore, the animal cannot let go its muscular or its siphuncular point of attachment to the old septal surface until the new one is made ready; hence the dipping down from layer to layer of the Oyster's shell-muscle; hence also the curious funnel-like tubes in *Nautilus (Aturia) ziczac*.

Although the Tetrabrauchiæ division of Cephalopods is only known by a single living genus, the Pearly Nautilus, in Silurian times it was represented by thirty-four genera and above 1,600 species. The shell in all the animals of this division is, geometrically speaking, an extremely elongated cone, either straight or variously folded and coiled. The Paleozoic species, of which *Orthoceras* is the type, had simple sutures, not complex, as is the case with the Secondary forms; but they underwent the same variations in curvature between straight in *Orthoceras*, bent on itself in *Ascoceras*, curved in *Cyrtoceras*, spiral in *Trochoceras*, discoidal in *Gyroceras*, produced discoidal in *Lituities*, and involute in *Nautilus*.

All the shells, as in Nautilus, are furnished with a siphuncle, sometimes having the appearance of a string of beads, at others like the vertebral column of some higher animal. The largest British *Orthoceras* does not exceed five to six feet in length, but they have been met with in America ten to twelve feet long, and of proportionate bulk. From faint indications of colour-bands it seems probable the shell was not an internal one, like the Belemnite, but rather like the modern Nautilus, external to the soft parts of the animal. In the *Goniatites* and the *Ammonites* the septa of the shell have most complex borders, which leave their impress upon the shell, and are called its sutures. They are highly ornamental in the Ammonites, often resembling the foliage of plants in pattern. The siphuncle, which is mostly central in *Orthoceras*, is marginal in *Ammonites*, running along the middle of the keel of the shell.

In the recent Nautilus the two "dorsal" arms are soldered together and expanded into a thick hood or operculum of tough and rugose epidermis. In the fossil Ammonites calcareous matter is added, thus forming a bi-lobed shelly operculum, or lid, which closely fits the mouth of the shell in many of the species, and has been found *in situ* in a specimen of *Ammonites subradiatus* from the Inferior Oolite of Dundry, near Bristol. One species from the Lias has a horny operculum. Thus we have in *Nautilus* and *Ammonites* a perfect analogy to the Gasteropoda, in which there are Snails without opercula, Snails with horny opercula, and others with shelly opercula.

More than 700 species of *Ammonites* have been described, extending from the Carboniferous of India to the Chalk, and they were of world-wide distribution.

In the Chalk a number of Cephalopodous shells have the appearance of having become "uncurled," and assumed fantastic forms of growth, as straight, folded in two, hooked, spiral, open spiral, trumpet-shaped, discoidal in the young state, and uncurled in later life.

The Tertiary Nautili differ but little from their modern representatives, save one form, named *Nautilus (Aturia) ziczac*, from the curious bent pattern of the septal partitions. In this form the siphuncle is not continuous, but is made up of a series of rather thick funnel-shaped nacreous tubes fitting one into another. This species is repeated, in a modified form, in the Secondary rocks, and by what is believed to be a Paleozoic representative in New Zealand.

HENRY WOODWARD.

CHAPTER II.

THE GASTEROPODA.

"Shell-fish"—Uses of the Shell—The Kinds of Shells—Economical Uses of the Mollusca in the Earliest Period and in the Present Day—Form and Growth of Shells—Parts of a Shell—Order I. PROSOBRANCHIATA: (a) SIPHONOSTOMATA—Siphonated Gasteropoda—Family I. STROMBIDÆ—"Wing-shells"—2. MURICIDÆ—Murex, the Source of the Celebrated "Tyrian Purple" Dye—"Mitre-shells"—Fusus, the "Red Whelk"—Whelks used for Food—Hemifusus, one of the Largest of Living Shells—3. BUCCINIDÆ—Buccinum, "Triton's Shells"—The "Dog Whelk," Nassa—Purpura—Its Dye—How it Tackles its Prey—Magilus Boring in Coral—The Harp-shells—The Olives—4. CASSIDIDÆ—Cassis—"Cameo-shells"—Triton—Use of the Shell as a Trumpet—Growth of Sea Snails—5. CONIDÆ—The "Cones"—Their Beauty and Commercial Value—Conus Gloria-maris—Terebra, the "Augur-shell"—6. VOLUTIDÆ—Rarity of the Volutæ—7. The CYPRIDIDÆ—Cowries—Richness of their Colour and their Value—Past and Present Prices of Specimens of Rare Shells—The Money Cowry—Cuttle-fishing with Cowry Bait—Shells as Articles of Ornament in Dress—Ovulum.

CLASS II.—GASTEROPODA.

INTRODUCTION.

Among the various natural objects which the ingenuity of man in all ages has converted into articles of use or ornament, both in savage and civilised life, none have attracted a greater amount of attention, or have been more in request, than the shells of Mollusca, especially sea-shells. Their bright colours and diversity of form are amongst their chief charms to the uninitiated; whilst to the student of natural history they offer ample materials for scientific research.

The shell in the Mollusc may be regarded as a hardened, or calcified, portion of the mantle, specially provided (like the enclosing ribs of the vertebrata) to afford protection to the breathing organs and heart. Indeed, when reduced to a mere rudiment, as in slugs, such as *Limax* and *Testacella*, or in the Marine Snail, *Carinaria*, &c., it forms only a hollow cone or plate protecting these organs. This structure (which has sometimes been called a pneumo*-skeleton) is so characteristic of the Mollusca as to have obtained for them the title of *Testacea*,† and the common name of "shell-fish" very well expresses the leading feature in the group. Nevertheless, in several families, the shell is either wanting altogether, or is internal, or so rudimentary that it would never be popularly recognised as a shell. When fully developed, the shell of the Mollusc subserves to protect the soft parts of the animal from injury, and the animal itself from the attacks of enemies; and in some of the Gasteropoda from those variations of temperature and moisture to which the terrestrial species are peculiarly exposed.

Shells are often called the "habitations" of fishes, or of marine animals, or Snails. Every one has seen the device of a Snail, with the motto, "always at home," on juvenile letters. The quarrymen of the Cotswold Hills go so far as to call some fossil shells snail-houses, the same epithet which they apply to the empty shells of the common Garden Snail. The term is not quite correct, for they are more properly skeletons, and we do not "inhabit" our bones, though Byron calls the skull a "tenement," and "the palace of the soul." Nevertheless, the expression is sufficiently indicative of the sense in which it is popularly used, and may pass muster without any further challenge on our part.

One fine summer afternoon we visited the fish-house of the Zoological Gardens, and paused to watch the manoeuvres of a Hermit Crab housed in a whelk-shell. Just then a lady of distinguished appearance called the attention of her friends to the same truculent animal, and expressed her lively satisfaction at having become acquainted with "the creatures which made that kind of shell." We hope before long that our readers will attain to a better acquaintance with the original fabricator of that common object of the shore, and will know how the forms and patterns of shells are suited to the wants and welfare of their proper owners.

It may be seen at a glance that many shells are bivalves,‡ like the Oyster and Cockle, while a few called "Chitons" are multivalve;§ but the great majority are single-valved, or univalves, and sometimes tent-shaped, like Patella, or tubular, as in *Aspergillum* and *Dentalium*, *Vermetus*, and

* From *pneuma*, the breath.

† From *testa*, a shell.

‡ Two-valved.

§ Many-valved.

Siliquaria ; but for the most part spiral, though exhibiting an endless diversity in their proportions as well as in their sculpturing and colour.

All insects, crabs, and other articulate animals are symmetrical, having the organs in pairs, *i.e.*, the right side like the left. In Corals and Star-fishes this two-sidedness is usually disguised by a radiate arrangement of the parts. But in Snails the symmetry of the eyes, tentacles, and other organs of the head is lost in the body of the creature. Instead of a double heart and two series of gills, these organs are single, and placed on one side. When on the left side, the growth is from left to right, to provide space, but in shells which are symmetrical, like the Pearly Nautilus, the Keyhole Limpet, and the *Ampullaria*, the gills are developed symmetrically on each side, or nearly so.

The tendency to grow in a spiral form is very characteristic of the class Mollusca. Some writers have accounted for it in a very matter-of-fact way. "Molluscous animals are long and worm-like, therefore Nature has coiled them up, that their tails may not be an incumbrance to them." It is easily ascertained that the Snail has a small spiral shell when it first quits the egg, and the young Whelk may be examined while still a prisoner in the same capsule with its brothers and sisters. The convenience of the arrangement is obvious, and that may be sufficient for us at present, but the time is coming when naturalists will desire to look more closely into these things.

How happens it that the embryo Snail, coiling itself up closely in its narrow cell, almost always takes a direction from left to right, following the course of the sun, and forming a dextral spiral, or right-handed shell, like an ordinary screw? Such a course is not absolutely necessary, neither is it accidental. A few Whelks and Garden Snails—perhaps one in ten thousand—are left-handed, and certain kinds of Whelks and Land Snails are as frequently reversed as right. The greater part of the genus *Clausilia* (numbering upwards of two hundred species) is reversed. The species of the genera *Physa* and *Triforis* appear to be always reversed. All the specimens of *Fusus contrarius*, so abundant in the Red Crag, and also found living in Vigo Bay, on the coast of Spain, are left-handed. But after all these latter are the exceptions. Every one familiar with garden plants will have noticed that the hop turns round its pole in one direction, going to meet the light, while the scarlet-runner takes an opposite course, as invariably as the sun it follows.*

Shells owe their variations in form to a number of circumstances. Those which assume a spiral, vary in being either turbinated or discoidal in their growth, and again, in the infinite gradations between the extremes of these two. The shape of *Conus* is an inverted triangle, that of the "telescope shell" (*Cerithium telescopium*) is trapezoidal, and so on. The turbinated shells again merge into forms in which the whorls become detached with age, as in *Vernatius* ; or a nearly straight tube, like *Dentalium*. The discoidal shells graduate into forms having fewer and fewer convolutions, and wider and simpler mouths, until at last, in forms like the Limpet, all spirality is lost, and we have only a tent-shaped cover.

At almost the earliest period in which we discover evidence of the existence of man, we find the primitive races dwelling upon the sea shore, and subsisting largely upon Mollusca ; leaving at one point shell-mounds of oyster-valves, associated with rudely-fashioned flint knives, employed in opening them ; at another, the broken fragments of turbinated univalves, and the round stone hammers used in crushing the shell to procure the *bonne-bouche* it enclosed. Nor did the mere cravings of hunger impel them to seek shell-fish as articles of food, for in the limestone caverns of France and Belgium numerous remains of shells of Mollusca have been met with, pierced with holes for the purpose of attaching them to some article of dress or head-gear.

Among the aborigines of the present day, in whatever region of the earth they dwell, the same economic uses of Mollusca prevail, and their practices serve to throw much light upon the fragmentary remains of their pre-historic ancestry.

The second class of Mollusca, called *Gastropoda*†—from the fact that the animals included in it habitually creep or glide by the successive expansion and contraction of the under side of the body, which forms a broad muscular foot—is well exemplified by the common Garden Snail. If one of these be watched through a window-pane in the act of creeping on the surface of the glass, the muscular movements of the foot may be seen following one another in rapid wave-like rhythmical succession.

* Unluckily, the botanists have chosen to reverse the terms employed in mechanics, and call the spiral of the hop right-handed.

† *Gaster*, belly ; *pous*, foot.

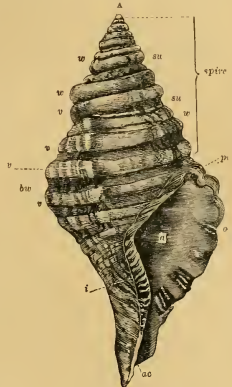
Nearly all Gasteropods are unsymmetrical, the body being coiled up spirally, having the breathing organs on the right side developed and those on the left absent. A few are like the Cephalopoda in being bilaterally symmetrical, as *Chiton* and *Dentalium*, in which the gills and ovaries are found on each side. With a few exceptions, in which the young Snails are born like their parent, the greater part deposit eggs, either in the water or in damp situations on the land. All are provided with a shell when first hatched, but this (in some genera) is found to become concealed by growth in the adult, or disappears altogether in later life.

The creeping Snails are, like the Cephalopoda, divided into two natural groups by their breathing organs—in the one they breathe air, and are hence called *Pulmonifera*,* in the other the gills are bathed in water, and they are named *Branchifera*.

Before proceeding further, it may be well if we clearly understand what are "the points" about a univalve shell, so that in enumerating the salient features of each genus our readers may comprehend and follow us in these descriptions.

The subjoined lettered figure of a shell of the genus *Triton* may serve to indicate, better than whole chapters of description, by what terms each portion of the shell is named.

This shell may be described as fusiform:† the apex (A) mammillated; ‡ the whorls (w) ventricose, § strongly ribbed or corrugated, with non-continuous varices || (v), and distinct sutures ¶ (su); the columella ** (i) is denticulated; †† the outer lip (o) is internally plicato-dentate; ‡‡ the anterior canal (ac) is elongated; the body-whorls (bw) are large; the aperture (a) ovately-elliptical.



SHELL OF TRITON.

ORDER I.—PROSOBRANCHIATA.§§

In the first order of Gasteropoda, called *Prosobranchiata* by Milne-Edwards, the gills are pectinated, or comb-like, and are placed in advance of the heart. The soft parts are protected by a shell into which the body of the animal can usually be withdrawn. The eye pedicels and the tentacles, or feelers, are on the same stalk.

Division a.—SIPHONOSTOMATA.|||—The proboscis is long and retractile, and the breathing chamber is provided with a tube, or siphon, to convey a fresh current of water to the comb-like gills. The members of this section are carnivorous and marine in habit, though some, as the "Strombs," are carrion-feeders.

FAMILY I.—THE STROMBIDÆ.

The *Strombide*, or "Wing-shells," are very active; they have large eyes, placed on thick pedicels, which are more perfect than those of other Gasteropods, or even of many fishes. They have powerful lingual teeth of a type peculiar to the carnivorous Sea Snails.

The Strombs (*Strombus* ¶¶) generally have a widely-expanded outer lip with an elongated aperture, lobed above and situated near the notch of the anterior canal. The whorls of the spire are often covered with tubercles or spines; and the spire of the shell is usually short.

* *Pulmo*, a lung; and *fero*, I bear.

† Spindle-shaped, pointed at both ends: from *fusus*, Lat., a spindle.

‡ From Lat., *manilla*, a test, a rounded summit.

§ From Lat., *ventricosus*, inflated.

|| Lat., *varix*, a swollen vein; in reference to the periodic mouths or ridges on the whorls of some shells, marking rests in growth.

¶¶ Lat. *sutura*, a seam; the point where two whorls of a spiral shell are united.

** Lat., *columella*, a small column or pillar; the axis of a spiral shell, around which the whorls of the shell grow.

†† From Lat., *dens*, a tooth; hence denticulated, bordered with small teeth.

‡‡ Lat., *plica*, a fold, and *dens*.

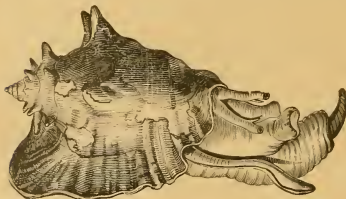
||| From *siphon*, a tube, and *stoma*, a mouth.

§§ *Proson*, in front; *branchiata*, gilled.

¶¶ From *strombos*, a top.

The great *Strombus gigas*, the "Fountain-shell" of the West Indies, is one of the largest of living shells, weighing sometimes four or five pounds. As it becomes old the animal fills up its apex and spines with solid shell matter.

Immense quantities are annually imported from the Bahamas for the manufacture of cameos, and for the porcelain works. Prof. T. C. Archer states that 300,000 were brought to Liverpool alone in



SHELL OF STROMBUS GIGAS, WITH THE ANIMAL.

1850. Strombs are common to the West Indies, the Mediterranean, Red Sea, Indian Ocean, and Pacific. Their favourite resort is on reefs at low water, down to ten fathoms' depth. Sixty species are known living, and many species occur fossil in the Miocene Tertiaries of Europe.

"Though the natives of the Antilles possessed few natural advantages over the inhabitants of the volcanic and coral islands of the Pacific, yet the abundance of large and easily wrought shells invited their application to many useful purposes, and accord-

ingly, when first visited by the Spaniards, the large marine shells, with which the neighbouring seas abound, constituted an important source for the raw material of their implements and manufactures. The great size and the facility of workmanship of the widely-diffused *Pyralis*, *Turbinella*, *Strombi*, and other shells have indeed led to a similar application of them among uncivilised races wherever they abound. Of such, the Caribs made knives, lances, and harpoons, as well as personal ornaments, while the Mollusc itself was sought for and prized as food. In Barbadoes, the *Strombus gigas* still furnishes a favourite repast, and numerous weapons and implements made from its shells have been dug up on the island. Plain beads formed from the columellæ of *Strombus gigas* have been found in the ancient graves of Tennessee, Kentucky, and Indiana. The columellæ were found worked to a uniform thickness, perforated through the centre, and in nearly all stages of manufacture, to that of perfect beads and links of much prized wampum.*

In the "Scorpion-shell" (*Pteroceras*)† the outer lip is produced in the adult shell into several long claws, one of which joins to the spire of the shell and forms the posterior canal. On account of its singular form this has been christened the "Spider," or "Scorpion" shell.

The genus *Rostellaria*,‡ or the "Spindle-stromb," is marked by having a very much elongated spire and long canals to its shell; the posterior one runs up the surface of the spire; the outer lip is sometimes expanded. In the great *Rostellaria ampla*, from the Middle Eocene of Barton, Hants, the adult animal puts forth a widely-expanded lip, as broad as one's hand, forming an immense "flange," or ear. Five species are found in the Red Sea and on the coasts of Borneo, India, and China.



PTEROCERAS LAMÉI.

FAMILY II.—MURICIDÆ.

The *Muricidæ* are extremely varied in form, having three rows of many-coloured spinous fringes, produced at nearly coincident intervals on each whorl of the shell, and becoming longer with age. "Venus' Comb" (*Murex tenuispina*) is an instance of this, the canal of the shell being produced to twice its length, and fringed with three rows of long and slender spines, slightly curved like the teeth of a harrow. In *Murex adustus* the spines are extremely picturesque, reminding one of a branching fir-tree. The Murices form only one-third of a whorl annually, ending in a *varic.* Some species form intermediate varices of lesser extent.

An abundant form, common on the English coast and around the Channel Isles, is called the "Sting-winkle" by the fishermen, who say it makes round holes in the other shell-fish with its

* Daniel Wilson's "Pre historic Man."

† From *pteron*, a wing; and *keres*, a horn.

‡ *Rostellum*, a little beak.

beak. The lingual teeth of *Murex* seem well fitted for thus boring through the shells of other Molluscs on which all these sea snails are predatory.* The dye used in the manufacture of the celebrated "Tyrian purple" of the ancients was obtained from certain species of *Murex*. The small shells were bruised in mortars, and the animals of the larger ones were taken out. Heaps of broken shells of *Murex trunculus* and canldron-shaped hollows in the rocks may still be seen on the Tyrian shore. (Wilde.) M. Boblaye noticed that on the coast of the Morea there is similar evidence of the employment of *Murex brandaris* for the same purpose. One hundred and eighty living species have been noticed; they are of world-wide distribution.

The *Muricide* not only possess the power of forming, but also of dissolving parts of their shells, and they use it in removing those external spines which, in the onward and continuous growth of the shell, would interfere with the comfort and convenience of the animal.

Columbella is the name given to a genus of small but prettily-marked shells, living in shallow water, on sandy flats, or congregating on stones, having a long narrow aperture, a thick outer lip, dentated within, the inner lip being crenulated and the operculum very small. About 200 species have been described, all being sub-tropical and widely distributed. The *Columbella mercatoria* of the West Indies was formerly used by the natives as "wampum" for barter or exchange.

The genus *Fusciolaria* (from *fusciola*, a band) is an elegantly-formed shell, with round or angular whorls (like a *Fusus* in shape), having bands of colour running down its sides; the inner lip has several oblique folds on it. The operculum is claw-shaped. Like the preceding genus, some species of *Fusciolaria* attain a very large size. The *Fusciolaria gigantea* of the South Seas attains a length of nearly two feet.

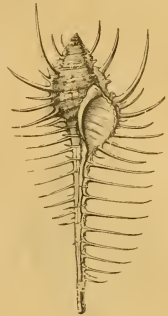


MITRA EPISCOPALIS.

The genus *Mitra* (the "Mitre-shell") has an elevated spire, with an acute apex; the shell is thick, the aperture small, and notched in front, the columella being obliquely plaited, and the operculum very small. The animal has a very long proboscis, and when irritated it emits a purple liquid, having a nauseous odour. Its bright colour-bands and ornamentation have led to the names of "Mitre-shell," "Bishop's Mitre," "Tiara," &c. This is a very abundant form. Three hundred and fifty species are known ranging from low water to a depth of eighty fathoms. They are mostly denizens of the tropical seas. Many of them must be very abundant, and yet a scientific person who only invests shillings in the purchase of shells may go on for twenty years and find himself only in possession of a few species, and of one common and brilliantly-coloured sort—the *Mitra episcopalis*. The most beautiful of the Mitras is properly called *regina*, but the rarest is *M. stainforthii*, valued at £10, of which Mrs. De Burgh possesses the original example. The same lady has the only specimen in England of the equally valuable (but not equally beautiful) *M. zonata*, which was brought up by the lead of a sounding-line from deep water off Nice, and described by Marryat in the *Linnean Transactions* of 1817.

The *Turbinella* (or "Top-shell") is a very thick, solid shell, with a short spire and a long canal. On the columella are several transverse folds. On the coast of India, China, Siam, Tranquebar, and Ceylon the Shank-shell (*Turbinella pyrum*) is carved by the natives, and placed in their temples. The reversed variety is held sacred by the Cinghalese, and from it the priests administer medicine to the sick. Another species is called the "Pap-boat" (*Turbinella rapha*). "It is used," says Sir J. Emerson Tennent, "on the Malabar coast (when scooped out internally and carved externally) to contain the sacred oil which is employed in anointing their priests."

The "Spindle-shell," *Fusus* (called the "Red Whelk" on the coasts of the Channel, and the "Buckie" in Scotland), is extensively dredged for the markets, being more esteemed in the north than



MUREX TENUSPINA.

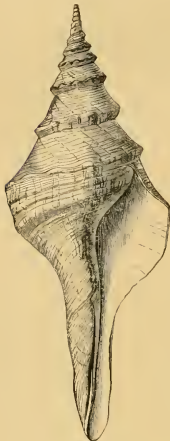
* For a description of the lingual teeth, or "odontophore" of snails, see p. 222.

the common Whelk (*Buccinum undatum*) as an article of food by the poorer classes. The shell is fusiform, with a many-whorled spire, and a long straight canal; the operculum is oval and curved, with the nucleus at its apex. *Fusus* has a world-wide distribution. Over one hundred species are described, many of which are sub-tropical.

The *Fusus antiquus* is extensively sold in Scotland, and also in Liverpool. It is the "Roaring Buckie," in which the sound of the sea may always be heard. Indeed, from its abundance and its size, it is very frequently used by children in the manner described in the exquisite lines of Wordsworth:—

"I have seen

A curious child applying to his ear
The convolutions of a smooth-lipped shell,
To which, in silence hushed, his very soul
Listened intensely, and his countenance soon
Brightened with joy; for murmuring from within
Were heard sonorous cadences, whereby,
To his belief, the monitor express'd
Mysterious union with its native sea."



FUSUS PROBOSCIDALIS.

The most valuable of the British univalves are some of the large Whelks; it is impossible to get a specimen of *Fusus turtoni*, even from the fishermen, for less than 30s., because it is only taken on the Scarborough coast, and there are always residents as well as visitors ready to buy it. A fine example would fetch three guineas in town. *Fusus dulei* is worth from three to five guineas; *Fusus berniciensis*, five guineas; and there are collectors who would give still more for the *Fusus fusiformis* if it could be obtained. The little *Stylifer turtoni*, found on the backs of Sea Urchins nestling among their spines, would have cost a guinea a few years ago, but has since been found in considerable numbers at Plymouth.

All the specimens of *Fusus antiquus* dredged in Vigo Bay, on the coast of Portugal, are found to be reversed (*i.e.*, sinistral, or left-handed spirals). *Fusus deformis*, found living off Spitzbergen, is also always reversed.

In Zetland, the *Fusus antiquus*, suspended horizontally by a cord, is used by the fishermen as a lamp, the canal serving to hold the wick, and the body of the shell the oil. (Fleming.)

Hemifusus colosseus and *proboscidalis* are two of the largest living Gasteropods. The latter has been found placed as an ornament on the graves of the aborigines in Australia. It attains a length of two feet. Some living species of *Fusus* are remarkable for the great length of the canal. This is the case in *Fusus colus*, in which it is twice as long as the rest of the shell.

The nest for hatching the fry of *Fusi* is curious in all the species. That of *Fusus norvegicus* consists of a lens-shaped bag, of an inch diameter, glued to the inside of shells. Mr. Howse says:—"The envelope is coriaceous, of a horny appearance, very transparent, smooth, glossy, and of a yellowish colour; one of the capsules contained three, the other only two, embryos. The last were far advanced, and apparently ready to leave the case. Through the transparent covering, when first dredged, I could see them moving about, and adhering to the inner surface of the capsule by the expanded foot, the sides of which were of a faint lilac colour. The thin operculum, the flattened tentacles, the diminutive spot-like eyes of these beautiful little creatures, were also distinctly visible. The young shell is very thin, brittle, pellucid, brilliantly glossy, and of a pale amber colour, nipple-formed, and perfectly resembles the nucleus, or upper whorl, of the adult individual. Those most advanced in growth have two whorls, and are half an inch in length by a quarter in width."

The capsules of *Fusus antiquus* are smaller, and placed above each other in a heap. The young are fully formed before they leave the capsule, but the young shell, which forms the nucleus or apex of the spire of the adult, is thin, rounded, and of a totally different character: hence the curious mamillated apex observed in all the species. (Sowerby.)

FAMILY III.—BUCCINIDÆ.

The *Buccinum*,* or “Triton’s shell,” is the type of another family of carnivorous Gasteropoda, in which the shell mouth is notched in front, or with the canal abruptly bent back. It has excellent lingual teeth for boring into shells with, and a long proboscis-like mouth and siphon, so that when burrowing after the living bivalves on which it feeds it can protrude its mouth into their gaping valves, or drill a hole even into the shell itself, if necessary; moreover, its long siphon is thrust upwards above the mud or sand, so that the animal can at the same time breathe freely. It requires only the opportunity to study the form and habits of the animal inhabiting these snail-houses to perceive that nearly all the peculiarities in the form of shells relate to some special function or habit of life of the animals which inhabit them.

One of the most important functions to be provided for in Snails is that of respiration. In univalves, the aperture of the shell is usually found to be characteristic of the division to which the animal belongs, the mouth being entire in most of the vegetable feeders, and notched, or produced into a canal in the carnivorous families (or *Siphonostomata*). But this canal, or siphon, is respiratory in its office, and must not, therefore, always be taken as a certain and sure indication of the nature of the animal’s food. Thus, for example, *Scalaria pretiosa* has a holostomatous, or perfect aperture to its shell, but is known to be carnivorous in its diet. If we refer to the Dog Whelk (*Nassa reticulata*) and the common Whelk (*Buccinum undatum*), we shall see the long incurrent siphon protruding from the canal of the shell and turned upwards. Into this tube the water passes, and enters a vaulted chamber (formed by an inflection of the mantle of the animal), which contains the pectinated, or plume-like gills. After traversing the length of the gills, it returns and escapes through a posterior siphon, generally less developed than the anterior one, but very long in *Ovulum colea*, and formed into a tube in *Typhis*. The object of the long siphon in the Whelk is to enable it to respire freely while burrowing in the sand in search of its prey—the poor defenceless *Mya*, and other bivalves.

The shell of the *Buccinum* is few-whorled, the whorls are ventricose, the aperture of the shell is large, the canal very short and bent back on the shell, the operculum is lamellar, and the nucleus is external. The *Buccinum* is characteristic of the northern seas, extending from low water to 140 fathoms. Twenty living species have been described. (See No. 2 in figure on p. 196.)

All round the British coasts and on the shores of Ireland the Whelk is dredged for the market, and is used as bait by fishermen. Many tons of them are annually consumed in the streets of the poorer parts of London.

The exterior of the shell of the Whelk is invested with a thin straw-coloured membrane, or epidermis, whose existence is scarcely recognised. Shells from a quiet soft sea-bed often have a coat like brown velvet. Many exotic Tritons are remarkable for their rough cuticle. All the Whelk tribe have horny opercula, and the pattern is often characteristic of the genus; the operculum is never spiral. Gregarious animals, such as the Whelk and Periwinkle, exhibit malformations more frequently than do others; thus we have Whelks with double opercula, others with shells repaired after injury or curiously contorted. A large percentage in particular localities are met with having the shell reversed.

The nidamental capsules of *Buccinum* are aggregated in roundish masses, and often attached to other shells, which, when thrown ashore and drifted by the wind, resemble horny corallines in appearance. Each capsule contains five or six young, which, when hatched, have each a tiny, stumpy, inflated spiral shell, very unlike the adult, of which it becomes, in course of growth, the apex.

The genus *Pseudoliva*† has a thick globular shell, with a deep spiral furrow near the front of the body whorl, and forms, like *Monoceros*, a small tooth in the outer lip; the spire of the shell is very short and the suture channelled; the inner lip is thickened so as to form a callosity; the mouth of the shell is notched in front. Six species are named from South Africa.

The genus *Haliotis*‡ was for many years a great puzzle to naturalists. It was only known by the existence of one or two shells in collections, and its habitat was lost. In general form

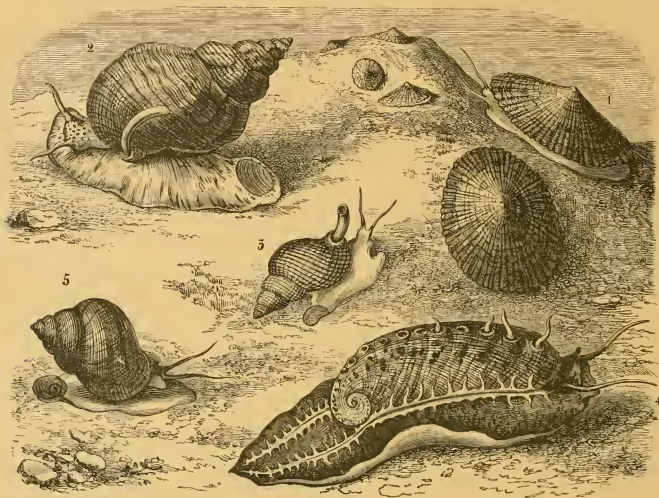
* *Buccina*, a trumpet.

† From *pseudos*, falsehood; and *liva*, from its resemblance in form to *Oliva*.

‡ From *halios*, of or belonging to the sea.

it is like a land-shell of the genus *Achatina*, the shell being ventricose, and smooth, the apex regular and obtuse.

Notwithstanding the fact that the fossil species of this rare and interesting shell had been found in true marine deposits in Italy associated with sea-shells, and sometimes coated by a coralline (*Lepralia*), yet Dr. Gray for many years adhered to the opinion that *Halio* was a true Land Snail, and placed it as such in the British Museum shell-collection. At length Mr. R. D. Darbishire, of Manchester, having learnt that the specimens hitherto sold had been certainly obtained at Cadiz, set out for Spain, and, by showing a shell (which he carried with him for the purpose) to the fishermen on



GROUP OF SEA SNAILS—1, *PATELLA VULGATA*; 2, *BUCCINUM UNDATUM*; 3, *NASSA RETICULATA*; 4, *HALIOTIS TUBERCULATA*; 5, *LITTORINA LITTOREA*.

the coast, was rewarded by obtaining several living specimens from deep water off the lighthouse. Cadiz, thus proving the correctness of the evidence derived from the fossil shells from Italy.

The genus *Eburna* (*ebur*, ivory), or "the Ivory-shell," is a thick, solid, smooth shell, with a short spire, umbilicated when young, but the umbilicus is covered by the callus of the inner lip in the adult. These shells have usually lost their epidermis, and are then pure white, spotted with dark-red; the animal's body is also spotted like the shell. Nine species are known from the Red Sea, India, and China. It extends also to Australia and the Cape.

The "Dog Whelk" (*Nassa**) has a shell like *Buccinum*, but is much smaller; the columellar lip is thickened by a callus, and expanded, so as to form a tooth-like projection near the anterior canal. The animal has a broad foot with diverging horns in front, and two little tails behind. *Nassa reticulata* is common on the English shores at low water, and is called the "Dog Whelk" by fisher-

* *Nassa*, a basket used for catching fish.

men. Two hundred and ten species are known, extending from low water to fifty fathoms. They are world-wide in their distribution.

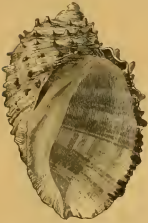
In *Purpura*, the shell is striated, or tuberculated, with a short spire and a large aperture, slightly notched in front, the inner lip being flattened.

Behind the head of *Purpura lapillus*, the only species that Britain possesses, is a receptacle containing a white fluid, which, on exposure to the air and light, reaches a brilliant tint through several intervening gradations of yellow, green, and blue.* The dye so obtained is made permanent without difficulty; but, although it was formerly used in Irish manufactures, it has long since ceased to be so employed, perhaps through not being procurable in sufficient quantity to make it worth collecting. The egg-bags of the *Purpura lapillus*, commonly called the "Dog Periwinkle," are deposited on the surface of rocks, or stones, or shells, united in considerable numbers to a common membrane, on which they stand erect like so many oval cups, each cup containing an embryo. Here the young *Purpura* remain for some months before the cup opens, and when this happens they do not all take immediate advantage of the new-born privilege, but some of them prefer remaining where they are for a time, in ease and comfort, till they acquire sufficient strength and courage to leave the protection of their cells.



PURPURA LAPILLUS.

Purpura, like *Littorina*, crawls about on the shore between watermarks, and seldom ventures under the lower tide-mark. It is very destructive to the mussel-beds. Gliding stealthily among the sea-weed and stones, it seeks its prey, and woe to the small Winkle, Limpet, or Trochus that comes within reach of its terrible proboscis. It will bring the aperture of its own shell opposite to that of its victim, and then, introducing its trunk, never leaves it until all the soft parts are transferred to its own capacious stomach. But even where no aperture or door leaves the smaller molluscs open to the attack of his enemy in that way, he is by no means deterred by this little difficulty, for if the object of his attack be a Limpet firmly attached to a stone, or a bivalve tenaciously holding its shell closed, he will manage to perforate the shell, and, through the hole, to draw forth the quivering substance. Mr. Spence Bate relates, that by way of experiment, he placed a *Purpura* in a vessel of sea-water in company with a Mussel, and observed the result. In a short time the *Purpura*, finding that the Mussel was not at all open to his advances, and that the valves of the shell were so firmly drawn together as to leave no chance of effecting an entry between their edges, began to think of attacking him from without. Seeking a portion of the outer surface free from epidermis, he commenced boring. His human observer, repudiating the policy of "non-interference," removed him, and turned the Mussel over, placing that valve uppermost which was most covered with the horny protection. The creature soon managed to turn over the huge body and shell of the Mussel, and resumed his operations at the point where he left off when disturbed, and he did this repeatedly after similar interruptions. At last, quite satisfied that the breach would in time be effected in this way, Mr. Bate resolved to wait no longer for the process, but at once to give the voracious sea snail an opportunity of satisfying its appetite at a



PURPURA PATULA.

smaller demand of exertion from itself and of patience from its observer. To this end he cut the muscles of the bivalve, so as to deprive it of the power of keeping its valves closed. Its fate was thus accelerated; it was now at the mercy of its enemy. The latter no sooner perceived the valves open than, leaving his former work of boring, he seized his advantage by inserting his trunk between the valves, not in this instance realising to the full the general rule, that the enjoyment of an acquisition is increased in proportion to the difficulty and trouble of obtaining it. When not so unexpectedly assisted, however, the hungry *Purpura* exhibits much patience, occupying himself for a couple of days in making his way through a mussel-shell. After gorging himself with a large portion of its contents, he lies for weeks without attempting to procure a fresh supply.

* The animal can always be induced to discharge its dye by pressing on the operculum.

Upwards of one hundred and forty species of *Purpura* are known and described; they are almost world-wide in their distribution, and extend from low water to twenty-five fathoms.

The "Unicorn-shell," *Monoceros*, is peculiar to the West coast of America, whence eighteen species have been brought. The shell is like that of *Purpura*, but with a spiral groove on the whorls, ending in a prominent spine, or tooth, at the lower or anterior end of the outer lip.

Magilus is a truly remarkable Molluscan genus, living parasitic, and boring in live Coral in the Red Sea, and on the coasts of Mauritius and Java. When young, the shell of *Magilus*, like any ordinary sea snail, is spiral and thin, with its aperture channelled in front; as it grows older, the shell ceases its spiral growth, and is prolonged instead into an elongated, irregular tube, at the extremity of which the animal resides, having in its onward growth filled up its original spiral shell and the greater part of the tube with solid shell-matter, compact and somewhat translucent, like aragonite. Formerly it was believed that the *Magilus*, which lives fixed in the living Coral, grew upward with the growth of the zoophytes in which it becomes immersed; but from specimens obtained, imbedded in the Coral itself, Mr. Charlesworth has shown that *Magilus* grows horizontally, eating its way through the Coral near the living surface, so as probably to reach and devour the zoophytes within, and yet always to remain concealed until the mass of the Coral is cut open, exposing the tortuous and solid, but once tubular shell. It is interesting to notice that in every case in which any animal, say a Crustacean or a Mollusc, becomes parasitic, it invariably loses some of its organs by disuse, and becomes malformed. Witness the "Hermit-crabs" living in sea snails' shells; the *Teredo* in timber; the *Siliquaria* in Sponges; and the *Magilus* in Coral, and many others. When we

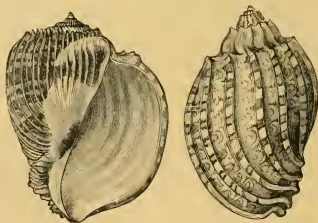
MAGILUS ANTIQVUS.—A,
YOUNG; B, ADULT.



consider that the coral-boring *Magilus* advances through the *Meandrina*, or other compact Coral, not by the movement of its shell, but by the slow, onward growth of the animal itself, eating its way through the living Coral mass, we can the more readily understand whence it obtains such a store of lime, sufficient to enable it to fill up the deserted earlier portion of its shell with so compact and solid a mass of crystalline material. In the British Museum is a Coral in which a *Magilus* has resided for a long time, and traversed the mass in a tortuous manner, leaving its solid tube behind. In one place, a *Lithodomus*, a bivalve Mollusc, also in the habit of making burrows into the same Coral, has driven its shaft at right angles to the tube of the *Magilus*, and has cut its tunnel right through the solid portion of the shell of the *Magilus*, regardless of its greater density. The tube of *Magilus* is sometimes as much as fifteen inches in length, and very heavy. The animal has a concentric lamellar operculum, with its nucleus near the outer edge. Only one species has been described, the *Magilus antiquus*.

The "Harp-shells" (*Harpa*), so called from the numerous sharp, smooth ribs placed at regular intervals on the surface of the shell, like the strings on a harp, form a group of elegantly-marked and coloured shells. The shell is ventricose, the spire is small, the body-whorl and aperture of shell large, and notched in front. The animal has a very large foot, with the front crescent-shaped, and divided from the posterior part by deep lateral fissures, which are said to separate spontaneously when the animal is irritated. It has no operculum. Nine species are described, all of which are tropical. *Harpa* lives in deep water, on soft, sandy, or muddy bottoms.

The "Olives" (*Olivæ*) are a numerous family, all with cylindrical, highly-polished, often very prettily marked and coloured shells. The spire is very short, the suture is channelled; the aperture is long, narrow, notched in front; the columella is thickened and obliquely striated; and the body-whorl



HARPA IMPERIALIS.

HARPA ARTICULARIS.

is furrowed near the base. All these highly-enamelled Gasteropods owe their beautiful polished surfaces to the fact that the mantle lobes are so large as to meet over the back of the shell, and so effectually protect it from all erosive action. The animal has a very large foot, in which the shell is half buried. The eyes are placed near the tips of the tentacles.

The Olives range from low water to twenty-five fathoms. All the species are very active; they may be seen gliding about near low water, or burying themselves in the sand as the tide retires. They are animal feeders, and attach themselves to the baits on fishing-lines at the bottom.

The Olives are all sub-tropical. One hundred and seventeen species have been described.

The genus *Ancillaria* resembles *Oliva*, both in its animal and its shell. It is said by d'Orbigny to use its mantle lobes for swimming. The shell has a larger spire than in *Oliva*, and the shell and spire are entirely covered with shining enamel.

In *Ancillaria glabrata* there is formed a sort of umbilicus between the thickened inner lip and the body-whorl. The *Ancillarias* are all sub-tropical shells. Twenty-three species are living.



OLIVA ERYTHROSTOMA.



OLIVA PORPHYRIA.

FAMILY IV.—CASSIDIDÆ.

The shells of this family are very much inflated (ventricose) and somewhat globose; the whorls are often ornamented with *varices*, or ridges; the aperture shows a re-curved canal in front; the outer lip is thickened in most; and the inner lip is wrinkled or granular. The "Helmet shells" comprise many of the largest known Gasteropods. They principally inhabit the warmer regions of the globe.

Cassis has a thick tumid shell, with a very short spire, a long aperture, the outer lip bent back and toothed, the inner lip being spread over the body-whorl; the canal is reflected in front. It has a small elongated operculum.

Many of the shells of this species, as *Cassis rufa* and the "Queen-Couch" (*Cassis madagascariensis*), are employed in the manufacture of shell-cameos. The best shell for cameo-engraving is the *Cassis rufa*, from West Africa. The secret of cameo-cutting consists simply in knowing that the inner stratum of porcellaneous shells is differently coloured from the exterior. Cameos, in the British Museum, carved on the shell of *Cassis cornuta*, are white on an orange ground; on *Cassis tuberosa* and *madagascariensis*, white upon dark claret colour; on *Cassis rufa*, pale salmon colour on orange; and on *Strombus gigas*, yellow on pink.



CASSIS CANALICULATUS.



CASSIS MADAGASCARIENSIS.

Cassis inhabits shallow water. Thirty-four species are living in the tropical seas of to-day. A shell of the genus *Cassis* has been found in the Pre-historic Cave-habitation of Les Eyzies, in Dordogne.*

Dolium, or the "Tun," as this shell is sometimes called, has a large thin, light ventricose shell with transverse ribs or furrows; the spire is short, the aperture very large; the canal is short and reflected; the outer lip is crenated; it has no operculum. Fifteen species are met with in the Mediterranean, India, China, the West Indies, Brazil, New Guinea, and the Pacific.

The genus *Cassidaria* is found living in the Mediterranean. The shell is ventricose and tuberculated; the aperture is narrow, ending in a produced and re-curved anterior canal; the inner lip is plicated, and spreads widely over the body-whorl; the outer lip is reflected and crenated.

In *Triton*—the shell usually painted in all mythological pictures as being blown as a horn by sea-deities attendant upon Neptune and Amphitrite—the "periodic mouths," or rests, form alternating

* See "Reliquiæ Aquitanicæ," p. 179.

nodes (or disconnected *varices*) up the spire to the slender apex. Both the inner and outer lip of this genus is denticulated or toothed. More than one hundred species have been found living in the temperate and sub-tropical seas, ranging from low-water to fifty fathoms.

The great *Triton* (*T. tritonis*) is the conch-shell blown by the Australian and Polynesian Islanders. The use of turbinated or spiral shells as trumpets or horns, to sound an alarm with, appears to be of most ancient date and cosmopolitan in extent. The practice is followed among the African aborigines, the natives of the Eastern Archipelago, New Zealand and Japan. "The sound of the trumpet or shell" (writes Ellis, in *Polynesian Researches*, vol. i., p. 283), "a species of *Murex* (*Triton*) used by the priests in the temple, and also by the herald and others on board their fleets, was more horrid than that of the drum. The largest shells were usually selected for this purpose, and were sometimes above a foot in length, and seven or eight inches in diameter at the mouth. In order to facilitate the blowing of this trumpet they made a perforation, about an inch in diameter, near the apex of the shell; into this they inserted a bamboo cane, about three feet in length, which was secured by binding it to the shell with finely-braided cinet. The aperture was rendered air-tight by cementing the outsides of it with a resinous gum from the bread-fruit tree. These shells were blown when any procession marched to the temple, at the inauguration of the king, during the worship at the temple, or when a tabu or restriction was imposed in the name of the gods. We have sometimes heard them blown. The sound is extremely loud, but the most monotonous and dismal that is possible to imagine." Specimens of these shells may be seen in the Shell Gallery, and also in the Ethnographical Room at the British Museum, prepared for use as horns by the South Sea Islanders.



TRITON VARIEGATUM.

The genus *Ranella* is an ovate-oblong compressed shell, having two rows of continuous varices (or periodic mouths), one on each side, from the apex down the spire to the mouth; the canal is short and re-curved, and the outer lip crenated.

The species of *Ranella*, fifty in number, are mostly tropical; the thicker and more rugose forms are found in rocky situations, and on coral reefs; the winged species, with smoother surfaces, are from deep water. The animals are active, and crawl rapidly. (Adams.) They are chiefly from India.

"Sea Snails," says Dr. S. P. Woodward, "certainly take many seasons to attain their maturity, even supposing them to grow twice a year. Dredging operations are usually only carried on in the spring and summer months; yet a large proportion of the mollusca taken are immature. *Eufima* grows a whorl at a time, then thickens its lip and rests; ultimately a straight line is found running down one side of the shell, caused by the coincidence of those 'rests.' In *Ranella* the line of 'rests' is also coincident; but as it only grows half a turn between each there are two rows down the spire."

Pyrgula (from the diminutive of *pyrus*, a pear) is the name given to a genus of sub-tropical shells known also as "Fig-shells." It has a fig-shaped or pear-shaped shell, with a short spire; the surface of the shell in many species is ornamented with raised reticulated lines; the outer lip of the shell is thin, and the inner lip smooth; the canal is long and open. It is nearly enveloped in the lobes of the mantle which almost meet on the back of the shell. The animal has a broad truncated foot, but no operculum. The Fig-shell has a wide sub-tropical range. Forty species are described living at from seventeen to thirty-five fathoms' depth.

Specimens of *Pyrgula perversa* and *Pyrgula spirata* have been found in grave-mounds and sepulchral depositories in different parts of Western Canada, illustrating the extent of traffic carried on between the north and south in ages prior to the displacement of the red man by the European.

FAMILY V.—CONIDÆ.

The great family of the Cones is characterised by the remarkably persistent form of their shells, being an inverted cone, with a very long and narrow mouth, and a sharp edged outer lip. Clothed in



CONES AND VOLUTES.

- 1, *Conus imperialis*; 2, 3, 4, *annularis*; 5, *C. nobilis*; 6, *C. gloria-maris*; 7, *C. textile*; 8, *C. geographus*; 9, *C. tessellatus*; 10, *Voluta scapha*; 11, *V. musica*; 12, *V. vexillum*; 13, *V. cymbium*; 14, *V. undulata*; 15, *V. imperialis*; 16, *V. delesserti*.

a dull, yellowish-brown epidermis, they offer no peculiar attraction in the living state. But when this natural covering is removed, and the shells have been carefully cleaned by a skilled hand, we are struck by the extreme beauty and diversity of patterns and colours which they display.

"The Cones," says Adams, "are principally inhabitants of the equatorial seas. Haunting the holes and fissures of rocks, and the labyrinths of coral-reefs, they lead a predatory life; boring into the shells of other molluscs and sucking the juices of their bodies."

Nearly three hundred living species have been described.

The genus *Conus* embraces many of the most highly-prized shells which are known to collectors. "Individuals," writes Dr. S. P. Woodward, "of many species are almost as abundant as the Cowries, while a few, and these are amongst the most conspicuous, are exceedingly rare." The *Conus neptuni*, in Mr. Cumming's collection; * *Conus caledonicus*, in that of the Baron Delessert; and *Conus brownii*, in the cabinet of M. Bowin, are considered unique. A specimen of *Conus thalassiarachus* was sold for £4 15s.; and good specimens of *Conus nobilis* are worth from £3 to £6. The "Admiral" (*Conus ammiralis*) is a beautiful shell, although no longer esteemed a great rarity; but *Conus cedonulli* has maintained its fame for a century, on account of the variety of painting it exhibits, and the extreme rarity of fine examples. A specimen was sold at Mr. Harford's sale for £16. The rarest of all Cones, and perhaps of all shells, except the living *Pleurotomaria*, is the *Conus gloria-maris*, which those old pagan Dutchmen worshipped, as did the Greeks the Paphian Venus. Perhaps it was this cone of which a Frenchman is related to have had the only specimen, except one belonging to Hwass, the great Dutch collector, and when this came to the hammer he outbid every rival, and then crushed it beneath his heel, exclaiming, "Now my specimen is the only one." Doubtless many traditions respecting the *Conus gloria-maris* yet linger in Amsterdam marts, in England it is still worth ten times its weight in gold. The Museum specimen formed part of the collection of the late Mr. W. J. Broderip, who gave £70 for it; and a second, in the cabinet of Mrs. De Burgh, was originally obtained from Holland for the late Mr. Norris, of Bury, a veteran collector, who expressed himself highly privileged to become the possessor in his old age of such an unexpected treasure.† The Cones range northward as far as the Mediterranean, and southward to the Cape; but they are most abundant and varied in the equatorial seas. They are found in shallow water down to forty or fifty fathoms. The animal moves slowly, and some species (as *Conus anticus*) bite when handled. (Adams.)

The shells of the genus *Pleurotoma*‡ are turreted, fusiform, with an elevated spire, an oval aperture, and a long and straight canal; the columella is smooth, the outer lip being notched in front and having a deep slit near the suture. The eyes are at the outer bases of the tentacles, which are wide apart. The mantle has a slit in the hinder part on the right side; the siphon is straight. The operculum is pointed, with an apical nucleus. This is a most prolific genus, numbering about five hundred species, and distributed from Greenland to the Cape; they are, however, most numerous in Asiatic waters, and are met with from low water-mark to one hundred fathoms.

The *Terebra*, or "Auger-shell," as it is called, from its long, pointed, many-whorled shell, like a borer, has a short canal, a small mouth, and a pointed operculum. The siphon is long and re-curved. The animal, in some species, is blind, and in others has the eyes at the extremity of minute tentacles. All the shells of this genus are smooth, and ornamented with variegated spots, generally red, brown, and orange colour. They are widely distributed over the world. One hundred and ten species are described, most of which are tropical.



TEREBRA
TIGRINA.

FAMILY VI.—VOLUTIDÆ.

The shell in this family is notched in front for the siphon, the columella is regularly and deeply plaited, and the operculum is absent. The animal has a very large foot, partly covering the shell, the siphon is re-curved, and the eyes are placed at the base of the tentacles.

* Now in the British Museum.

† "Recreative Science," 1860.

‡ *Pleura*, the side; *tome*, a notch.

"The 'Volutes' have large and fine shells, elegant in their form, and often remarkable for their painting and rich colour. They are tropical shells, numbering about one hundred species, and have been grouped in about half a dozen sections or sub-genera, examples of some of which are difficult to obtain. The *Voluta abyssicola*, supposed to be the living representative of the fossil Volutes of the London Clay, is now only known by a unique specimen from deep water off the Cape, formerly in the collection of Mr. Louie Taylor. The *Voluta antica* was unique until Mr. Cumming's return, and Sowerby valued the Tankerville specimen at forty guineas. *Voluta fulgetrum*, in the same collection, was priced at £31, and *Voluta papillosa* £21. The fine *Voluta junonia* in the British Museum is worth £40; and the less conspicuous *Voluta piperata*, acquired at M. Vernèze's sale, was valued at £16. The *Voluta reticulata* in Mr. Norris's collection cost £30; and Mr. Dennison gave £20 for the first specimen of *Oniscia dennisoni*, and his collection is remarkable for the number of fine and costly shells it contains." (S. P. Woodward.)

The Volutes extend from the littoral zone to one hundred fathoms depth. *Voluta junonia* was dredged in the Gulf of Mexico, at a depth of seventy fathoms.

The genus *Melo*, or the "Melon," has a large, somewhat oval, inflated shell, with a short spire, the apex of which is obtuse and rounded (mammillated), and the whorls are smooth. The columella has several oblique plaits on it, the outer lip is thin and simple, and the shell is truncated in front. Most of the species of *Melo* are ornamented with a variety of colours, and the whorls are adorned with a dialium of spines; the living shell is covered with a greenish-brown epidermis. The foot is large and thick; the eyes are at the outer bases of the tentacles. The animals of *Melo* and *Cymba* are both ovo-viviparous, bringing forth their young alive without egg-shells. The natives of the Papuan Islands use the shell of the *Melo* to bail out their canoes with. About ten species of *Melo* are described, principally from New Guinea.

The genus *Cymba*, or the "Boat-shell," is less elegant than the "Melon;" the embryo or apex of the shell is large and globular; the whorls few, and flattened. The writer has captured large numbers of the living *Cymba olla* in Catalan Bay, at the east side of the rock of Gibraltar, in the Mediterranean, cast ashore after a heavy sea from the south-east. They were trying to bury themselves by the aid of their huge foot in the sands, but the sun dried the sand faster than they could dig down, and so they fell a prey to the collector! Like *Melo*, it is ovo-viviparous, and the young, when born, are an inch in length. Ten species are described from the West Coast of Africa, the Strait of Gibraltar, and as far north as Lisbon.

Marginella is a smooth, bright shell, with a short or truncated spire, a narrow aperture, a plaited inner lip, and a thickened outer lip. The animal is like *Cyprea*. There are ninety species of these pretty little shells described, mostly tropical. Numerous beads have been found, made of the shells of the genus *Marginella*, in ancient graves discovered in Tennessee. The shells were ground down so as to make a perforation on the back, by means of which they could be strung together for purposes of personal ornament.

FAMILY VII.—CYPREÆIDÆ.

In this family the head of the animal is broad, the rostrum short, the tentacles long, the eyes placed on projections near their external bases, the siphon is long, the mantle has large expanded side-lobes covering the shell. There is a single branchial plume; the operculum is wanting.

The shell (as in all Molluscs where covered by the mantle-lobes) is usually smooth and polished; and the last whorl is large, convolute, and wholly or partially conceals the others; the outer lip is bent inwards, thickened, and toothed, the inner lip is dentated or corrugated. The mantle-lobes are often ornamented along their borders with filaments or serrated edges; sometimes, however, they are smooth and simple. The foot is large, expanded, and often greatly elongated behind.

"In their habits the Cowries are shy, and crawl slowly; they are nearly all tropical animals, inhabiting the warmer seas; and as they glide along among the coral reefs and in the shelter of rocks, with the lateral lobes of their mantles adorned with showy colours, they present to the eye of the naturalist objects of singular interest and beauty." (Adams.)

There are few shells that are more persistent in form than are the "Cowries." In *Cyprea* proper the shell is somewhat cylindrical in form when adult, varying, however, according to the

age of the animal: in the very young it is thin, pellucid, and like a snail-shell, it afterwards becomes like an *Olive*; finally, the outer lip is bent in and the inner lip is dentated; and we have the adult Cowry, in which we fail to detect the apex at all.

How much of the wonderful natural history of such common objects as the "shells from the sea-shore" is lost to the great majority of mankind; and yet what marvels are revealed to the eyes of the trained observer of nature! The beauteous shell of the Cowry lies concealed within the folds of its mantle; that of the Cone is covered by a thick rough epidermis, which has to be removed before its hidden beauties are discovered.

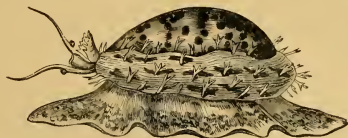
"God's works," writes Professor Forbes, "are never left unfinished. None is too minute for the display of infinite perfection. The microscope has exhibited to our wondering eyes beauties of structure that have been concealed from mortal sight for long ages. It would almost seem as if only glimpses of those excellences of creation are permitted to man to behold, whilst the full contemplation of such wondrous charms is reserved for immortal and invisible admirers."

But living Molluscs not only secrete shell-matter: they have likewise the power to absorb the internal convolutions and *columella* of their shells, either completely or until it is reduced to the thinnest film. The Cone removes all but a paper-like portion of its inner whorls, and the *Cyprea* often goes still further in removing all trace of its axis.

The Cowry owes the glassy polish of its whole exterior to the amplitude of its mantle, whose folds meet over its back, and ordinarily conceal the shell entirely. In the shining Marginellas, and Olives, and some Volutes, the shell is partially glazed by the same envelope. It is absolutely essential that the mantle should cover any part of the shell to which additions are required; any injury, therefore, beyond the reach of this mantle externally must be repaired from the interior. This will explain why the broken apices of univalves and the eroded umboes of the river Mussel are never repaired externally, but always by deposits within the spire or the valves of the shell.

The size of the adult shell is often characteristic of the species, but this is by no means uniform. The author has frequently seen specimens of *Cyprea turdus* equally adult, measuring three-quarters to one inch and a half, but the dwarf varieties are more common than the giants.

Since the year 1825, when George Sowerby catalogued and priced the Tankerville collection, shells have much diminished in pecuniary value, and shillings will now generally go as far as guineas did then. This depreciation has chiefly affected the deep-sea shells, which have become more plentiful since the employment of the dredge has been generally introduced, and land shells, which are mostly procured in abundance when their proper localities are understood. But some shells seem destined to be always scarce, like the Orange Cowry and the *Conus gloria-maris*. No doubt there are "as good fish in the sea as ever came to net," but sometimes they live in inaccessible places. Shell-collectors, like the old Dutch florists, have always set apart a few genera as the special objects of their affection, to which they attach a fanciful value. These are the Cones, Cowries, Mitres, and Volutes, with a few miscellaneous species belonging to other genera, such as the Thorny Oyster, Wentletrap, Carinaria, Harp, and Rostellaria. Most of the stories told about the extravagant prices paid for particular shells are probably apocryphal or grossly exaggerated. It is said that a Parisian "professor of botany" paid 6,000 francs (£240) for a Thorny Oyster (*Spondylus rejius*), and that a Dutchman gave an estate for a Wentletrap (*Scalaria pretiosa*). Now the *Scalaria* is worth from 5s. to 10s., and the finest *Spondylus* in England was purchased by Mrs. de Burgh for £5. The *Carinaria vitrea*, which, according to Sowerby, once realised one hundred guineas, is still worth £12 in the market, and fetched as much as £15 only a few years ago; but the value of fine specimens of this shell is enhanced by its extreme fragility. One of the Orange Cowries in the British Museum was purchased by Mr. Broderip of the late Mrs. Mawe for £30, although it has holes in it made by the natives; and fine



COWRY (*CYPREA TIGRIS*) AND ITS ANIMAL.

The Shell is here drawn exposed to view; it is usually entirely covered by the lobes of the mantle.

specimens are still worth ten guineas. The *Cypræa leucodon*, in the same collection, is unique, and worth £50; the *C. princeps* was valued at £60; and other examples have realised £40 at the Tankerville sale, and £40 at the sale of Mr. Holford's collection; Mr. Demison, of Liverpool, had one which cost £35. The specimen of *Cypræa guttata* in the British Museum is valued at £40; and the rare little *Cypræa borelayi*, when first brought to England, obtained £10; and *Cypræa guttata* has realised sums varying from £12 to £30, within the last ten years, and as the specimens are generally in poor condition, it is certain that fine examples would still command a high price. The cabinet of Miss Saul, of Bow Lodge, is considered to be richer than any other in this group of shells, and the late Mr. Gaskoin, who wrote a monograph of the genus *Cypræa* had a very extensive series, which afterwards was united to the magnificent collection of the late Mr. Lombe Taylor, of Starston. (S. P. Woodward.)

The Money Cowry (*Cypræa moneta*) is a native of the Pacific and Eastern seas. Many tons' weight of this little shell are annually imported into England, and again exported for barter with



MONEY COWRY.

the native tribes of Western Africa. In the year 1848 sixty tons of the Money Cowry were imported into Liverpool. Wilson says of *Cypræa moneta* :—"The Cowry shells used as currency are procured on the coast of Congo, and in the Philippine and Maldivé Islands. Of the latter, indeed, they still constitute the chief article of export. At what remote date, or at what early stage of rudimentary civilisation, this singular representative shell-currency was introduced, it is perhaps vain to inquire, but the extensive area over which it has long been recognised proves its great antiquity. The Philippine Islands form, in part, the eastern boundary of the

Southern Pacific, and the Maldives lie off the Malabar Coast, in the Indian Ocean; but their shells circulate as currency not only through Southern Asia, but far into the African continent."

In Ellis's "Polynesian Researches," vol. ii., p. 292, he gives an account of fishing for Cuttle-fish with an artificial bait, formed of a piece of hard wood, to which a number of the most beautiful pieces of the Cowry, or Tiger-shell, are fastened one over another, until it is about the size of a turkey's egg, and resembles the Cowries. It is suspended in a horizontal position by a strong line, and lowered by the fishermen from a small canoe until it nearly reaches the bottom. The fisherman continues gently to jerk the line, when the Cuttle-fish, attracted by the appearance of the Cowry, darts out one of its arms, which it winds around the shell, and fastens among the openings of the plates. The jerking being continued, the fish puts out another and another arm, till it has quite fastened itself to the shell bait, when it is drawn up into the canoe and secured.

One of the earliest uses to which the shells of Mollusca appear to have been applied was that of articles of dress. In MM. Lartet and Christy's "Reliquiæ Aquitanicæ" (Part III., 1866, B., Pl. v., Figs. 15-20) we find illustrations of several shells—viz., *Cypræa pyrum*, *Pectunculus glycineria*, *Arca breislaki*—which show clearly, by their having been perforated, that they had been worn either as ornaments or charms by the aborigines who inhabited the cave of La Madelaine. The custom of using shells, &c., as necklaces or other personal decorations, is common, not only amongst savages, but even amongst civilised races at the present day. In this case the shells have been obtained, not from river or sea, but from the Faluns of Touraine or Bordeaux, deposits of Miocene age, rich in fossil marine shells, many of which are so well preserved as to retain the glazed surface seen in recent specimens. Dr. Fischer, of Paris, has determined as many as five species in the caverns of Périgord.

An Oolitic Belemnite, having its sides squared by grinding, was found among the *débris* in the cavern of Bruniquel, département Tarn-et-Garonne; also an Ammonite and a Grypæa, probably introduced by children as toys. Perforated recent marine shells were likewise numerous. These relics are preserved in the British Museum. Shells are at the present day as greatly in demand for ornamental purposes as in pre-historic times. The Chinooks of Oregon ornament their noses and ears with shells of *Dentalium*. The Friendly and Fiji Islanders wear the Orange Cowry (*Cypræa aurora*) as a mark of chieftainship. The natives of Flinders Island and the New Zealander polish the *Elenchus* into an ornament more brilliant than the "pearl ear-drop" of classical or modern times.



COWRIES.

1, 2, *Cyprea undata*; 3, 4, *C. nucleus*; 5, 6, *C. madagascariensis*; 7, *C. mappa*; 8, 9, *C. histrio*; 10, *C. pantherina*; 11, *C. scottii* (young); 12, 13, *C. argus*; 14, *C. tigris*; 15, 16, *C. testudinaria*; 17, 18, *C. scottii* (adult).

Cypræa shells are worn as a head-dress by the natives of New Guinea. The time would fail in which to tell all the various methods used in applying shells as ornaments to the head, dress, and person. Every book of travels in Africa, America, or the South Sea Islands teems with such illustrations. Nor does India furnish an exception to the rule; for there the female children have their arms and ankles, from infancy, encircled with broad shell-bands, cut from the whorls of the great *Turbinella pyrum*, and the Sepoy troops wear necklaces, made from the canal of the same shell, as part of their parade uniform.

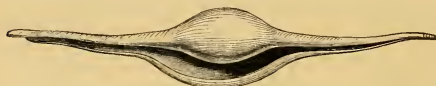
One hundred and fifty species of living *Cypræa* have been described. They occur in all the warmer seas of the globe, but are most abundant in the Old World.

The genus *Trivia* is peculiarly interesting to us, as it includes the only Cowry found upon the British coast—the *Trivia europæa*. The shells of this genus are sometimes covered with transverse raised ribs across the back, as in *Trivia europæa* and *T. pediculus*; and sometimes with elevated tubercles, as in *T. pustulosa*; or with both, as in *T. staphylea*. Thirty-five species are recorded; they are all small forms. Near the edge, at low water, you may sometimes see our little British *Cypræa* crawling on the sandy bottom. The animal is not more than half an inch long, of a bright orange colour, duskily banded, or yellow with orange edge, or all of a pale pink colour. In front are two slender tentacles, with small black eyes near their bases; between these horns is a small tube bent upwards—this is the siphon. The shell is wrapped up in the two lobes of the gaily-coloured mantle; the foot is square in front and very long and pointed behind. At the slightest touch the foot and mantle-lobes, feelers, and siphon all disappear, and the little flesh-coloured ribbed shell alone remains, all the soft parts being contracted within the narrow-toothed mouth of the shell, leading us to wonder how so tiny a shell is able to accommodate so large an animal.

The pretty little shells belonging to the genus *Erato* differ from *Marginella*, with which they have been confounded, in not having a marginal varix, or swelling, and from *Cypræa* in having distinct plaits on the columella; the outer lip, too, is thickened towards the middle and denticulated within.

One species (*Erato levis*) is found on the North British coast, and also in the Mediterranean. Eleven species are described from the West Indies and China.

The shells of the genus *Ovulum* (the "China shell") are



OVULUM VOLVA.

never ornamented with rich and varied colours, like those of the Cowry tribe, but are usually white, pink, pale violet, or yellow, without exhibiting any particular markings or pattern. The shell is like *Cypræa*, but the inner lip is smooth. *Ovulum volva* ("the Weaver's Shuttle") has the aperture of the shell drawn out into a long canal at each end. The foot is narrow, and adapted for clasping the round stems of the *Gorgonia*, on which the animal feeds. Thirty-four species are described, inhabiting the warmer seas of the West Indies, Mediterranean, China, and West America. Two species (*O. patula* and *O. acuminata*) are met with on English shores.

CHAPTER III.

THE GASTEROPODA (*concluded*) AND PTEROPODA.

Order I. (*concluded*)—(b) the Holostomata, or Entire-mouthed Sea Snails—Family 8. NATICIDÆ—9. CANCELLARIADÆ—10. PYRAMIDELLIDÆ—11. SOLARIADÆ—"The Staircase-Shell"—12. SCALARIADÆ—*Scalaria pretiosa*, the "Wentle-trap"—Great Value attached to this Shell—13. CERITHIADÆ—Potamides in Fresh Water—14. TURRITELLIDÆ—"Tower-shells"—15. VERMETUS—Worm-shells—16. PALUDINIDÆ—Fresh-water Snails—the "Apple Snail," *Ampullaria*—Its Tenacity of Life—17. LITORINIDÆ—Periwinkles as Food—18. CALYPTHEIDÆ—"Bonnet Limpets"—The Grotto-shells, *Phorus*—19. TURBINIDÆ—*Trochus*—20. HALIOTIDÆ—The Ear-shell, *Haliotis*—Uses of Pearly Shell—*Pleurotomaria*—Its Rarity—21. LANTHINIDÆ—*Lanthina*, "Floating Shells"—The Raft—22. FISICULIDÆ—23. NERITIDÆ—24. PATELLIDÆ—"Limpets"—Used as Food—How the Oyster-catcher Detaches them—25. DENTALLIDÆ—26. CHITONIDÆ—Multivalve Snails—Order II., PULMONIFERA—Air-breathers—Anatomy of a Snail—Inoperculata, or Land Snails without Operculum—Characters—Curious Experience of a Desert Snail—27. HELICIDÆ—Used as Food—The Largest Land Shell Known—The Odontophore, or Tooth-bearing Tongue—Other Genera—28. LIMACIDÆ—The Slugs—The Mucus Secretion and its Uses—29. ONCIDIADÆ—30. LIMNÆIDÆ—Air-breathing Pond Snails—31. AURICULIDÆ—Operculata, or Operculated Land Snails—32. CYCLOSTOMIDÆ—33. HELICINIDÆ—34. ACICULIDÆ—Order III., OPHISTHOBRANCHIATA—35. TORNATELLIDÆ—36. BULLIDÆ—37. APLYSIADÆ—"Sea Hares"—38. PLEUROBRANCHIDÆ—39. PHYLLIDÆ—The "Sea Slugs"—40. DORIDÆ—41. TRITONIDÆ—42. ÆOLIDÆ—43. PHYLLIROIDÆ—44. ELYSIADÆ—Order IV., NUCLEOBRANCHIATA—Oceanic Snails—45. FIROLIDÆ—The Carinaria—46. ATLANTIDÆ—Class III., PTEROPODA—Their Pelagic Character—Their Abundance—Source of Food to the Right Whale—Their Wing-feet compared to Moths—Delicacy of their Shells—Distribution.

Division b.—HOLOSTOMATA.*—In the section already described, the SIPHONOSTOMATA are marked (as we have seen) by the respiratory siphon protruding from the anterior canal of the shell, indicating their carnivorous propensities. In this section, the HOLOSTOMATA, the respiratory siphon is not (as a rule) so produced, and the mouth of the shell is therefore entire, and not drawn out into a canal in front. The animal has usually a short, non-retractile muzzle; the gills are comb-like or plume-like. Most of this division are vegetable-feeders and dwellers in marine or fresh water.

FAMILY VIII.—NATICIDÆ.

In this family the shell is globular, with few whorls; its spire is small and obtuse; the aperture is semi-lunar, with an acute lip; the pillar of the shell is often thickened by a callus. The animal has a long, retractile proboscis; the lingual ribbon is linear; the foot is very large, the mantle-lobes enveloping the greater part of the shell. All the species of this family are marine.

In the genus *Natica* the shell is smooth and thick and the inner lip callous; the umbilicus is large, having a spiral callus. The operculum is sub-spiral and shelly. The animal is blind; the foot is large, having a fold in front protecting the head; the lobes of the foot cover part of the shell. The animal is carnivorous, feeding on the smaller bivalves. (Gould.) They are themselves devoured by the Cod and Haddock and the larger Star-fishes. The eggs of the *Natica* are agglutinated into broad and short spiral bands, unattached. The animal frequents sandy and gravelly bottoms, from low water to ninety fathoms. (Forbes.)

The colour-markings on the shells of *Natica* are very indestructible; they are frequently preserved in fossil shells. The species are numerous; more than ninety have been described distributed from the Arctic Seas, the shores of Britain, and the Mediterranean, to India, China, America, Australia. They occur also in the Caspian.

In the genus *Sigaretus* the shell is ear-shaped, the aperture is very wide and oblique, the surface of the shell is striated, the operculum is minute, horny, and sub-spiral. The shells of the flatter forms are entirely concealed by the mantle of the animal; the convex forms are partially so. The epidermis is yellowish. The foot is enormously developed in front. Twenty-six species are described living in the East and West Indies, China, and Peru.

In the genus *Velutina* the animal has a thin shell and a velvety epidermis; the spire is small, the suture deep, and the aperture very large and rounded; the shell has no operculum. The margin of the mantle is developed all round, and turned up over the shell; gills, two; head broad; tentacles blunt, far apart, eyes at their outer bases. The animal is carnivorous. Four species are described from Britain, Norway, and North America.



NATICA PAPHIONIS.

* From *holos*, entire; *stoma*, mouth.

FAMILY IX.—CANCELLARIADÆ.

The animals of this family are remarkable for the simple nature of the oral apparatus, both tongue and teeth being wanting; the head, moreover, does not seem to be elongated, the rostrum being rudimentary; the operculum is also wanting. The shell has the aperture more or less channelled in front, and the columella is plicated. (Adams.)

The genus *Cancellaria** includes a large number of moderate-sized shells, the surface of which is cancellated or cross-barred, or reticulated by a double series of parallel lines, one running around the shell-whorls from the mouth to the apex, the others transversely, corresponding to the varices, or periodic mouths, of *Triton* and *Ranella*. There are several strong oblique folds on the columella. The animal has no operculum. Contrary to other members of this family, the animals in this genus are vegetable feeders. They are remarkable for the elegance of their shells. Seventy species are described from the West Indies, China, South America, and the Eastern Archipelago, ranging from low water to forty fathoms.

The genus *Trichotropis*, of Broderip, has a turbinate and thin, somewhat elevated, shell, more or less umbilicated, spirally furrowed and cancellated, often furnished with epidermal fringes on the ribs; apex of spine acute, aperture pyriform, outer lip simple acute, inner lip flattened, canal rudimentary. More than twelve species are described, mostly from the Northern seas, from fifteen to one hundred fathoms.

FAMILY X.—PYRAMIDELLIDÆ.

In this family the characters are: tongue unarmed; teeth none, or rudimentary; tentacles broad, folded ear-shaped, eyes at their inner bases; mantle enclosed with a siphonal fold; foot short in front, produced behind; operculum horny, sub-spiral; shell turreted, aperture entire, columella plaited. The species of this group are all marine, and probably predaceous and carnivorous, as they have a retractile proboscis.

The species of the genus *Pyramidella* live in sandy bays and on shallow mud-banks, concealing themselves under the surface, and indicating their presence by forming slender raised tracks. Eleven species occur in the West Indies, Mauritius, and Australia.

The genus *Odostomia* includes a number of very minute shells, having the habit of *Rissoa*, and, like them, sometimes found in brackish water. They range from low water to fifty fathoms. The shell is subulate or ovate, smooth; apex sinistral, aperture ovate, columella with a single tooth-like fold, lip thin, operculum horny. About thirty-five species have been described from British, Mediterranean, and Madeiran coasts.

The genus *Chemnitzia* was named in honour of Chemnitz, a distinguished German conchologist, of Nuremberg, 1780-95, and the author of a great work on conchology.

The shell is slender, many-whorled, the whorls plaited; apex sinistral; aperture simple, ovate; peristome incomplete; operculum horny, sub-spiral. The animal has a long retractile proboscis; eyes at inner bases of the triangular tentacles; foot truncated in front.

The genus *Chemnitzia* is world-wide in distribution. Seventy species are recorded from low water to one hundred fathoms.

Eulimella has an elongated, solid, many-whorled, smooth, polished shell; the mouth is sub-quadrate; peristome incomplete; columella straight, and smooth. Four species are described: from Britain, Norway, and the Mediterranean.

Monopygma is the name of a genus of shells of great beauty and delicacy, resembling greatly elongated forms of *Acteon*. The animal is nearly allied to *Actis* in its short tentacles, with the eyes at their inner bases, rudimentary tongue, and elongated narrow foot. Twelve species are recorded by Adams, from India, China, and elsewhere.

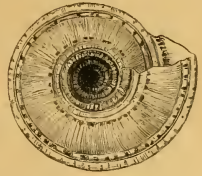
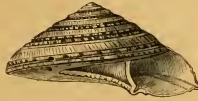
In the genus *Eulima* the shell is elongated, white, smooth, polished; the spire is produced, many-whorled; the apex is acute; aperture oval, pointed behind; the inner lip is reflected over the pillar, the outer lip is thickened internally. The *Eulima* crawl with the foot greatly in advance of the head, which is usually concealed beneath the margin of the shell. Many of them have distorted shells the upper whorls being often bent or inclined out of the straight line. Twenty-six species are recorded, from Cuba, Norway, Britain, Mediterranean, Australia, India, and other parts, in five to ninety fathoms.

* Latin, *cancellatus*, cross-barred.

Stylina has a glassy, globular shell, with a tapering apex and a sinistral nucleus. The animal has a thick mantle, which is bent over the last whorls of the shell. It lives attached to the spines of Sea Urchins, or buried in living Star-fishes and Corals. It is found in Britain, the West Indies, Philippines, and the Galapagos.

FAMILY XI.—SOLARIADÆ.

The proboscis in this family is retractile, and the tongue (according to the observations of Dr. Gray) is entirely unarmed; the tentacles are laterally folded, the eyes are on the uppersurface at their bases; the mantle is included; foot moderate, and formed for walking; the operculum horny, spiral, oval, or circular. The genus *Solarium*, or the "Staircase Shell"—so named because the spiral edges of the whorls seen in the umbilicus have been fancifully compared to a winding staircase—has a depressed orbicular shell, with a wide and deep umbilicus. The aperture of the shell is squarish, the peristome is thin, the operculum horny and sub-spiral. There are twenty-five species, all from sub-tropical and tropical seas, and very widely distributed.



SOLARIUM PERSPECTIVUM.

FAMILY XII.—SCALARIADÆ.

The animals in this family are predaceous. The mantle is enclosed with a rudimentary siphonal fold; the foot is obtusely triangular and grooved below; the tentacles are slender, and the eyes are placed at their outer bases; the operculum is horny and spiral. The shells are nearly all white; they are spiral and turreted, and are ornamented with varices; the aperture is circular, without any notch or canal. The shells are remarkable for their extreme elegance of form.

SCALARIA
PRETIOSA.

The genus *Scalaria*, known commonly as the "Wentletrap," or "Ladder-shell," has mostly a pure white lustrous shell, the whorls of the turret-like shell being round and nearly separate, merely united by the sharp transverse ribs. When molested, the animal exudes a purple fluid. The species exceed one hundred in number, and range from low water to one hundred fathoms. Most of the species are tropical, but there are exceptional species found on the coasts of Greenland and Norway. The others are almost world-wide. In the "Wentletrap" (*Scalaria pretiosa*) the periodic mouths encircle the shell whorls, which are sometimes separate, and contribute not a little to the beauty of this once costly conchological treasure.

FAMILY XIII.—CERITHIADÆ.

In this family the shell is spiral and many-whorled, the mouth of the shell is channelled in front, and the outer lip is usually expanded in the adult shell. The animal has a broad and short rostrum, with the tentacles wide apart; the eyes are on short stalks united to the base of the tentacles. The mantle-margin has a rudimentary siphon-fold in front; the foot is broad and short, and angular in front; the operculum horny and spiral. The members of this family are met with in marine, estuarine, and fresh-water localities.

The genus *Cerithium*, or the "Horn-shell," has a turreted, many-whorled shell, with indistinct varices; the canal is produced in front, and slightly recurved; the columella is thickened and callous behind. *Cerithia* are found in all parts of the world. More than one hundred living species have been described.

*Potamides** is the name given to a group of fresh-water *Cerithia*, with thick olive-brown epidermis, and an orbicular many-whorled operculum. They are found chiefly in the Old World, especially in Africa and India, inhabiting the mud of large rivers.

The genus *Aporrhais*, or the "Spout-shell," is a shell with an elongated spire, composed of

CERITHIUM
ALCOO.

* From *potamos*, a river; and *cidos*, used in the sense of species.

numerous tuberculated whorls, the aperture narrow, but the outer lip greatly expanded, lobed, and digitated; the operculum is pointed and lamellated. The muzzle of the animal is short and broad; the tentacles are cylindrical; the eyes are on prominences near their outer bases; the foot is short, rounded in front, pointed behind. Three species are described living at twenty to one hundred fathoms, in Labrador, Norway, Britain, the Mediterranean, &c.

*Struthiolaria** is a turreted shell with angular whorls. Its aperture is truncated in front; the columella is very oblique; the outer lip is prominent, thickened; inner lip callous, expanded; operculum claw-shaped. Five species occur in Australia and New Zealand.

FAMILY XIV.—TURRITELLIDÆ.

The shell in this family is tubular or spiral, the upper part being partitioned off. The aperture of the shell is simple; the operculum horny, many-whorled. The animal has a short muzzle, eyes on head at the outer bases of the tentacles, mantle fringed, foot short, tongue armed. This is a strictly marine group, the species ranging from low water-mark to a depth of one hundred fathoms. Their geographical distribution extends over most of the countries of the globe, one species being an inhabitant of the British seas. They are commonly called "Screw-shells," from their peculiar form.

In the genus *Turritella* ("Tower-shells"), the shell is turreted, many-whorled, spirally striated, the aperture round, margin thin. The shells of this genus are spotted and variegated, generally with red and brown. The species inhabit all parts of the world, being most numerous in tropical countries. The writer has taken the *Turritella communis* by the dredge-fall off the Bay of Malaga (Mediterranean), showing that they are gregarious in their habits in soft mud. Many examples were dredged showing the whorls disconnected, as in *Vermetus*. Fifty species are described of world-wide distribution.

When young, the shell of the genus *Cæcum* is discoidal; when adult, it becomes decollate, and appears to be simply tubular, cylindrical, with a round entire aperture, the apex being closed by a mammillated septum, marking the point where the original spire has been cast off. This curious little genus has puzzled many zoologists, having been referred to the Pteropods, to the *Orthoceratites*, &c. Two British species have been met with living in about ten fathoms water.

In the genus *Vermetus*, or the "Worm-shell," the shell is tubular and attached, but when young it is regularly spiral, but always disunited and irregular in its adult growth. The tube is repeatedly partitioned off, the aperture is round, the operculum circular and concave externally. The animal has a rudimentary cylindrical foot, being unable to crawl or glide, as the shells are fixed together in clusters. *Vermetus* is found on the coasts of Portugal, the Mediterranean, Africa, and India.

The genus *Siliquaria* has a tubular cylindrical shell, irregularly twisted; its apex is spiral, the aperture is circular. In *Siliquaria* the notch for the siphon remains unclosed, so that as the shell grows it prolongs the fissure through the whole length of its tube. This genus was formerly regarded as an Annelid, but its molluscous nature was demonstrated by M. Audouin. The typical species is found in the Mediterranean, living embedded in sponges with silicious spicules. Eight species are recorded.

FAMILY XV.—MELANIADÆ.

The shells of this family are spiral, turreted, covered with a thick dark-coloured epidermis; aperture often channelled, or notched in front; outer lip simple; operculum horny, spiral. The spire is often very much eroded. The animal has a broad, non-retractile muzzle; the tentacles are wide apart; eye-stalks united to bases of tentacles; foot broad and short, angular in front; mantle-margin fringed; tongue long and linear. These animals are mostly viviparous, and all fluviatile, being inhabitants of fresh-water lakes and rivers throughout the



TURRITELLA
TERRELLI
LATA.



VERMETUS LUMBRICALIS.
(A) Young Shell; (B) Adult Shell.

* From *Struthio*, an ostrich, from the aperture being fancifully supposed to resemble the foot of that bird.

warmer parts of the world. In the southern States of North America they are numerous, and form a peculiar group.

The genus *Melania** has its whorls ornamented with striae or spines; the outer lip is sharp; aperture oval, pointed above; operculum sub-spiral. One hundred and sixty species are distributed along the rivers of the south of Europe, India, the Philippines, and Pacific Islands.

The genus *Paludomus* (*palus*, marsh; *domus*, house) has a smooth turbinated or muricated shell. The spire is small, and usually eroded; operculum horny, lamellar, nucleus external. The animal is like *Melania*, with a fringed margin to its mantle. Ten species are known from Ceylon and India. It inhabits mountain streams, sometimes up to six thousand feet in elevation.

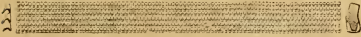
The shell of *Melanopsis* has the last whorl elongated; the spire is short and pointed; the aperture notched in front; the inner lip is thickened; the operculum is sub-spiral. Twenty species of this genus are found in Spain, Austria, Asia Minor, and New Zealand.



MELANIA
AMARI LA.

FAMILY XVI.—PALUDINIDE.

The shells of this family are conical or globular, with a thick olive-green epidermis; the aperture of the shell is rounded and entire; the operculum is horny, or shelly and concentric. The animal has a broad muzzle; the eyes are placed on short pedicels outside the tentacles, which are long and slender. The *Paludinide* inhabit fresh water in all parts of the world. The animal of *Paludina* has a small lobe on each side of its neck. It has a long muzzle and very short eye pedicels. The shell is thin, turbinated, umbilicated; the spire is produced; the whorls are round and smooth. The development of

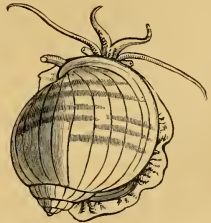


LINGUAL TEETH OF AMPULLARIA.† (After S. P. Woodward.)

the gill-bearing Gasteropods may be easily seen in the common River Snail (*Paludina vivipara*), which bring forth their young alive, and whose oviducts in early summer contain young in all stages of growth, some being a quarter of an inch in diameter. Embryos hardly visible to the naked eye have a well-formed shell, ornamented with epidermal fringes, a foot, and operculum. The head has long and delicate tentacles, and very distinct black eyes. Any one who is interested in mollusca may watch this for himself, as *Paludina* is common in our ditches and marshy waters. Sixty species are described as abundant in rivers and lakes throughout the Northern Hemisphere, Africa, India, China, Manila, and elsewhere.

Valvata piscinalis is a little fresh-water mollusc, which has the foot divided in front into two lobes. The shell is round and horny, much shorter than *Paludina* or *Bithynia*. The animal deposits her eggs in a little leather bag, which she hangs on stones or the stems of water-plants, where they remain till they are hatched, and liberated from their bag by the bursting of its rotting sides. They all leave their prison in company, being united in a floating mass of jelly.

The *Ampullaria*, or "Apple Snail," has a globular shell with a small spire. The body whorl is large and ventricose; the operculum is shelly; the left neck-lappet is formed into a long incurrent siphon; the muzzle is developed into two long processes, like horns; the tentacles are extremely long and slender. *Ampullaria* inhabits lakes and rivers in the tropics. They retire deep into the mud in the dry season, and are capable of surviving a long drought, having been known to revive after being kept for several years out of water. In Lake Mareotis, and at the mouth of the Indus, *Ampullariæ* are abundant, mixed with marine shells. Their eggs are large, enclosed in capsules, and form globular masses. Fifty species have been described from South America, West Indies, Africa, and India.



AMPULLARIA CANALICULATA.

* *Melania*, blackness.

† For description of the Snail's tongue, or "odontophore" (tooth-bearer), see page 222.

In *Amphibola* the shell is globular; the columella fissured with a channel near the suture of the outer lip; the operculum is sub-spiral and horny. The animal is without tentacles; the eyes are placed on round lobes. It is an air-breather. *Amphibola* inhabits salt marshes near the sea, living shells having *Scrupule* attached to them. They are found on the shores of New Zealand in great abundance, living in pools of brackish water, and burying themselves alive at certain seasons in the sandy mud. They are largely eaten by the New Zealanders.

FAMILY XVII.—LITORINIDÆ.

The mantle of animals of this family has a rudimentary siphonal fold; the gills are unequal, one very large; the head is muzzle-shaped, and the eyes are fixed at the outer bases of the tentacles; the foot is grooved along the under surface, and has a linear fold in front; the tongue, which is long, is furnished with seven rows of hooked teeth. The shell is spiral, top-shaped, or flattened; aperture simple in front, never pearly; operculum horny, spiral, the whorls are few.

Genus Litorina.^{*} The Periwinkle has a compact, solid, turbinate (top-shaped) shell of few whorls; the spire is short, the aperture nearly circular, without any siphonal channel; the outer lip is simple and sharp-edged. The horny operculum fits it most exactly. The *Litorina litorea* is collected in immense quantities around our shores, and is known by the familiar name of "winkles," or "pin-patches." This species is *oviparous*†, and inhabits the lowest zone of seaweed between tide marks. The *Litorina radis* frequents a higher region, where it is scarcely visited by the tide; it is *viviparous*,‡ and the young have a hard shell before birth, in consequence of which the species is not eaten.

Both the *Litorina* and *Trochus* are the food of the Thrush in the Hebrides during winter. Periwinkles are largely employed by oyster growers to keep the beds and the "culch"§ clean by eating up the slimy green weed that grows so abundantly on oyster beds, especially in hot weather.

More than forty species of Periwinkles are found living on the sea-shore in all parts of the world. When near the mouths of rivers (or as in the Baltic, which is less salt) they come in contact with fresh water, and are liable to become distorted.

In the caves of Southern France and Italy, along with mammoth and reindeer bones and ivory, and in the sepulchral deposits at Aurignac, have been found shell necklaces or bracelets made of the *Litorina litorea*, still abundant on the shores of the Atlantic, along with perforated shells of the Miocene period, evidently gathered in a fossil state to be converted to purposes of personal decoration. In the Megalithic tomb discovered in the year 1838 under the Knock-Maraidhe Cromlech, in the Phoenix Park, Dublin, were found two male skeletons, underneath the skulls of which lay a number of the common *Litorina litorea*, bored evidently for the purpose of being strung together as neck ornaments.

Genus Fossarus. This little shell is perforated, the spire is ribbed and striated, the inner lip is thin, the operculum is not spiral. Its distribution is India, West Africa, and the Mediterranean.

The genus *Lacuna* has a short spire, the shell is thin, the aperture is very large, the columella is flattened and umbilicated; it has a spiral operculum. The animal has lateral wings to its opercular lobes and tentacular filaments. The species inhabit the northern shores of Norway, Britain, and Spain, extending from low water to fifty fathoms.

Genus Litiopota.|| This minute shell has a pointed spire, the aperture notched in front, the outer lip thin; it has a spiral operculum. They are found floating on seaweed in the Atlantic and Mediterranean; they adhere by delicate threads.

The genera *Cheletropis* and *Macgillivrayia* are also found gregarious in the open sea, and have been referred to the *Pteropoda* by some, but Dr. S. P. Woodward refers them, in his later MS. notes, to the Litorinidæ.

Genus Rissoa. This minute white shell (named after Risso, a French zoologist) is conical, pointed

* From Latin, *litus*, *litoris*, the sea-shore.

† Oviparous, from *ovum*, an egg, and *pario*, to bring forth.

‡ Viviparous, from *vivens*, living, and *pario*, i.e., the young are born alive, as in *Polydora*.

§ Any foreign body to which the young Oyster attaches itself when it ceases to be a free swimmer.

|| Greek, *litos*, simple, and *opis*, aperture.

and many-whorled, some species being smooth, others ribbed or cancellated; aperture roundish, the operculum sub-spiral. The animal has its eyes on small prominences near the outer base of the tentacles, which are long and slender. The foot is pointed behind. The Rissoæ abound in shallow water on seaweed, and live down to a depth of 100 fathoms. Seventy species have been described; they are cosmopolitan in distribution.

Genus *Lithoglyphus*. This small shell has few and smooth whorls, and a large entire aperture. The outer lip is sharp; the operculum is ovate and few-whorled. It has an olive-coloured epidermis. It is found living in the Danube and Central Africa in fresh water. The shell is often eroded. D'Orbigny has described it from South America, under the name of *Paludestrina*. Seventeen species have been noticed.

Genus *Truncatella*, Looping Snail. This shell is cylindrical and truncated; aperture oblong-oval; operculum very thin and somewhat spiral. The species of this genus inhabit the East and West Indies, Britain, the Mediterranean, and the islands of the Corean Archipelago. The animals are amphibious in their habits, being sometimes found under heaps of seaweed on the shore, and sometimes in shallow water. In Corea they live gregariously, by many thousands, in the holes of decayed rock and coral which border, in many places, the islands; the spots they occupy are always exposed to the spray of the sea. (Adams.)

FAMILY XVIII.—CALYPTRÆIDÆ.

The "Bonnet Limpets." These shells have a more or less spiral apex, and, Limpet-like, adhere to foreign bodies. The interior of the shell is simple, more divided by a shelly process, to which the muscles are attached. The head of the animal is distinct, the muzzle is long, and the eyes are at the outer base of the tentacles.

"The Bonnet Limpets are found adhering to stones and shells; most of them appear never to quit the spot on which they first settle, as the margins of their shells become adapted to the surface beneath, while some wear away the space beneath their foot, and others secrete a shelly base. Both their form and colour depend on the situation in which they grow; those found in the cavities of dead shells are nearly flat, or even concave above, and colourless. They are presumed to feed on the seaweeds growing round them, or on animalcules. A *Calyptrea* which Professor Forbes kept in a glass ate a small Sea Slug (*Ganiodoris*) which was confined with it. Both *Calyptrea* and *Pileopsis* sometimes cover and hatch their spawn in front of their foot." (S. P. Woodward.)

Genus *Calyptrea*,* "Cup and Saucer Limpet." The shell is conical, with a minute spiral nucleus; the margin is irregular; interior provided with a half cup-shaped process, attached to the apex; outer surface of shell rough. The Cup and Saucer Limpets are found under stones in shallow water, between tide-marks. Fifty species are known of almost world-wide distribution.

Genus *Crepidula*, "The Slipper-shell." This shell is oval and Limpet-like; the apex is near the posterior margin; the interior has a shelly partition covering its posterior half. The *Crepidula* are sedentary on stones and shells in shallow water, and are sometimes found adhering to one another in groups of many successive generations. The specimens or species which live inside empty spiral shells are very thin, nearly flat, and colourless. Forty species occur recent, in the West Indies, Mediterranean, Cape of Good Hope, Australia, and America.

Genus *Pileopsis*.† The shell of the Bonnet Limpet is conical; the apex is behind, and is spirally curved; the aperture is rounded; the muscular attachment is shaped like a horseshoe. The animal has a fringed margin to its mantle. *P. ungarica* is found on Oysters. Seven species are living in Britain, Norway, the Mediterranean, East and West Indies, Australia, &c.

Genus *Hipponyx*.‡ The "Horseshoe-Shell" is thick, conical, oblique; its apex is behind; it has a shelly base, bearing a horseshoe-shaped impression. Seventy species are found living in the West Indies, Galapagos, the Philippines, Australia, &c.

Genus *Phorus*.§ The shell is, like *Trochus*, concave beneath and irregular; the whorls are flat, and more or less concealed by fragments of shell and stones; the spire is depressed, the aperture wide, the umbilicus small; it has a thin oval operculum. "The 'Carriers' inhabit deep water, and are

* Latin, *calyptra*, a lady's cap.

† Greek, *pīleos*, a cap, and *opsis*, like.

‡ Greek, *hippos*, a horse, and *onyx*, a hoof.

§ Greek, *phoreus*, a carrier. They are also called grotto-shells.

most numerous in the Javan and China Seas. Each species appears to have its own peculiar method of collecting the fragments of shells and stones which cover the ground where it lives, and each cements to the outside of the shell its particular kind of materials. The adventitious pieces of shell are so disposed as not to curve downwards beyond the edge of the shell so as to impede the progress of the animal, but are usually placed with their concave side uppermost." (Adams.) Nine species have been described; they are all tropical. Some species of these shells prefer to affix stones, whilst others select dead shells or corals for their grottoes. The former are called "mineralogists" and the latter "conchologists" by collectors.



PHORUS CONCHYLIOPHORUS.

FAMILY XIX.—TURBINIDÆ.

In this family the shell is turbate, the last whorl rounded and ventricose; aperture sub-circular, inner lip smooth and simple; operculum round, horny, with a solid convex shelly coat. In the great pearly *Turbo marmoreus*, so often used for a sideboard or mantelpiece ornament, the operculum frequently weighs several ounces. A specimen in the Shell Gallery of the British Museum weighs more than half a pound. The animal has a short proboscis; the eyes are at the outer base of the tentacles, which are long and slender; the head and sides are bordered by fringed lobes and filaments.

The shells of nearly all of the Turbinidæ are brilliantly pearly when the epidermis and outer layer of shell have been artificially removed.

Genus *Turbo*.* The shells of *Turbo* have solid convex whorls, often ornamented by furrows or tubercles; the aperture is large and rounded, the shell is pearly within. The outer side of the operculum in some species resembles tufa deposited by a petrifying spring; they are sometimes used for ornaments.

The Turbos inhabit the tropical seas; sixty species have been described. They are mostly littoral.

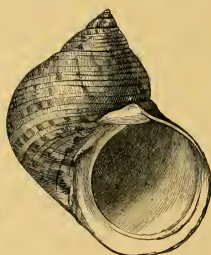
Genus *Phasianella*, the "Pheasant-shell." The spire of this shell is elevated, the whorls are smooth and polished, the aperture oval, the columella flattened, and the outer lip thin.

"When the animals of this genus crawl, the foot appears to be divided longitudinally into halves, which advance alternately: when the right side moves the left remains stationary, and when this in turn is carried forward the other half serves as a point of support. MM. Audouin and Milne-Edwards have observed that *P. pullus* exhibits the same mode of progression, which they compare to the amble or canter of a horse. In *Phasianella* proper the tentacles are provided with three cirrhi. In the smaller species, forming the *Tricolia* of Risso, the head-lobes appear to be wanting. The larger species, all of which have beautifully variegated shells, are principally from Australia and the islands of the Pacific, and the smaller species are from the West Indies and the Mediterranean." (Adams.) Thirty species are known living.

Genus *Imperator*. The shell is like *Trochus*, with a flat or concave base; the whorls are keeled or stellated; seen from above, it resembles the rowel of a spur, hence the name Spur-shell. The shell is pearly within, the operculum is oblong and shelly. Twenty species are known, from South Africa, India, &c.



TURBO ARGYROSTOMUS.



TURBO IMPERIALIS.

* Latin, *turbo*, a whipping-top.

Genus *Trochus*.* The shells of this genus are pyramidal, with a nearly flat base, the whorls are variously striated, the aperture is squarish and pearly inside, the outer lip is thin, the operculum is composed of many convolutions. There are 150 known and described species of this world-wide shell, extending from low water to more than 100 fathoms.

Genus *Eleutherus*. The shell in this genus is thick and polished, and there is usually a single tooth at the fore part of the columella: the aperture is vividly iridescent within, and the surface is often ornamented with varied and beautiful markings. This species is characteristic of Australia; fifteen have been described. They are polished and worn by the natives of North-east Australia as necklaces.

Genus *Rotella*. "the Button-shell." The shell is like porcelain, the whorls round and polished, the base or umbilicus covered with a large callosity, aperture small, outer lip acute. The upper part of the shell is banded with lines of colour. Eighteen species are recorded, from India, the Philippines, China, and New Zealand.

Genus *Mondolonta*, the "Rosary-shell." It is top-shaped, like the common Periwinkle in form; the whorls are grooved and granulated spirally, lip thickened and grooved, columella irregularly toothed, operculum whorled and horny. Ten recent species are known from West Africa, Red Sea, India, and Australia. They inhabit mangrove swamps.

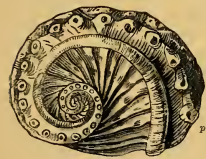
Genus *Delphinula*. The shell has few whorls, the apex is depressed, the angles of the whorls are rugose or spiny, the aperture is round and pearly within, the umbilicus is open, the operculum horny and many-whorled. *Delphinula* is found living on coral reefs at low water. Twenty species have been described, from the Red Sea, India, the Philippines, China, and Australia.

Genus *Cyclostrema*. This little shell differs from *Delphinula* in being nearly discoidal; the whorls are cancellated or cross-ribbed, and the inside of the shell is not pearly. Eighteen species are recorded, living in five to twenty fathoms water, at the Cape, India, the Philippines, &c.

Genus *Stomatella*. The shell has a minute spire and a very large oblique aperture; the interior is pearly; lip thin and even; operculum circular, horny, spiral. Twenty recent species are described, from the Cape, India, Australia, &c. The genus *Gena* differs but little from the preceding one, save in the absence of the operculum. Sixteen species have been described, mostly from the Philippine Islands, where they appear to represent the genus *Haliotis*.

FAMILY XX.—HALIOTIDÆ.

This shell is ear-shaped and spiral; the aperture is very large, pearly and iridescent within; perforated with a series of holes; there is no operculum.



HALIOTIS TRICOSTALIS.
(1) Perforation for siphon.

The animal has a short broad head, with eyes on stout stalks at the outer base of the tentacles; the left lobe of the mantle elongated into an anal siphon, occupies the anterior perforation of the shell; the foot is large, and very thick, with serrated lobes and filaments on the outer edges. With the true Ear-shells (*Haliotidae*) are placed such of the Trochiform shells as have a notched or perforated aperture.

Genus *Haliotis*.† "Ear-shell." The shell has a small flat spire and a very wide iridescent aperture; exterior striated, corrugated, and dull, often incrustated with corallines, &c.; outer angle perforated by a series of holes, which are successively closed. Seventy-five living species are known; they inhabit the littoral zone, and occur in Britain, the Canaries, India, Australia, and California, &c.

In the Ear-shell (*Haliotis*), found living on the rocks at low water in the Channel Islands and elsewhere, and so common a mantelpiece ornament, on account of its pearly interior, the ex-current

* Latin, *trochus*, a hoop.

† Greek, *haliōs*, marine, and *ous*, an ear.

siphon is accommodated by a hole near the lip of the shell, repeatedly renewed with the growth of the animal. In the Keyhole Limpet (*Fissurella*) the anal siphon passes through the perforation on the summit of the shell. The *Haliotis* abounds on the shores of the Channel Islands, where it is called the "Ormer," and is cooked, after being well beaten to make it tender. It is also eaten in Japan.

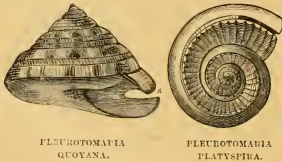
The late Mr. Daniel Hanbury, F.L.S., published some interesting "Notes on Chinese Materia Medica," in the *Pharmaceutical Journal* for February, 1862, from which I extract the following:— "*Shih-keue-ming* : shells of *Haliotis funebris*, Reeve; *Puntston*, &c. This shell is stated to occur on the coasts of Fo-kien and Quang-tung. Messrs. Cumming and Lovell Reeve (both since deceased), who have examined it, concur in referring it to *Haliotis funebris*, a New Holland species, figured by the latter gentleman in his beautiful *Conchologia Iconica*, sect. *Haliotis*, pl. xii., fig. 38. The shell of *Haliotis* is also much used for inlaying *papier mâché* work, &c. The section of any pearly shell exhibits an immense succession of fine and smooth layers. If polished or worn ever so little, these laminae will be cut through, and their edges will present a series of parallel lines. In the nacreous shell of *Haliotis* the layers are corrugated, so that a single layer might serve to give the pearly effect. In porcellaneous shells the entire structure is composed of layers of cells, much metamorphosed, arranged in three distinct strata, the direction of each of which is different. When seen in section, each stratum is found to be composed of many vertical plates, arranged sometimes transversely, sometimes lengthwise, according to the genus."

Genus *Stomatia*. The shell of *Stomatia* resembles *Haliotis*, but has no perforations, merely a simple furrow; the surface is rough and spirally ridged; the apex of the spire, which is small, is very prominent; the opening of the shell is wide and pearly within. Twelve species have been met with under stones at low water. Its distribution is the coasts of Java, Philippines, Torres Straits, Pacific.

Genus *Scissurella*.^{*} This minute shell is thin, with a large body whorl and a small spire; surface striated; the aperture rounded, but not pearly, with a slit in the margin of the outer lip; the operculum is ovate and very thin, obscurely sub-spiral.

The animal is like *Margarita*, with long and pectinated tentacles, the eyes at their base; foot with two pointed lappets and two long, slender, pectinated cirrhi on each side. No part of the animal was external to the shell. The only living example occurred at Hammerfest in forty to eighty fathoms water. When placed in a glass of sea water, it crawled up the side and scraped the glass with its tongue. It was pale and transparent when living, but turned inky black after immersion in alcohol. (Barrett.) The slit in the young shell is converted into a *foramen* in the adult, as in the Jurassic *Trochotoma*.

Genus *Pleurotomaria*.[†] "Slit-shell." The shell is like *Trochus*, it has few whorls; the surface is variously ornamented, the aperture sub-quadrate, having a deep slit in the outer lip. As the shell grows this slit is gradually filled up, and forms a distinct band round the whorls of the shell; it is not pearly. This is probably the rarest of all living sea-shells. Only two species have been obtained: one from the Antilles and one from the East Indies. Four hundred species occur fossil, chiefly in the Oolites.



FAMILY XXI.—IANTHINIDÆ.

In this family the characters are: shell thin, translucent, spiral, more or less turbate, with a sinistral nucleus; head short and thick; tentacles obtuse; eye pedicels pointed, but without eyes; gills plume-like, exposed; foot small, flat, rudimentary, having a raft-like appendage attached to the hinder part; habits pelagic.

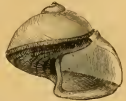
Genus *Ianthina*.[‡] "Violet Snail." Prof. Sir Wyville Thomson writes: "The genus *Ianthina* inhabits a spiral shell, like a Snail-shell, of a most lovely blue. *Ianthina* floats by spreading out its 'foot' on the surface, but it is more usually found attached to the different kinds of 'Portuguese men-of-war,' *Verella*, *Physalia*, and

^{*} Latin, diminutive of *scissus*, a slit.

[†] Greek, *pleura*, side, and *tome*, notch.

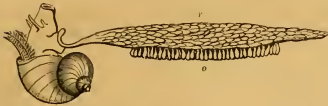
[‡] Latin, *Ianthina*, violet-coloured.

Porpita, or in the mid-Atlantic in the wandering islands of gulf-weed. At certain seasons a peculiar kind of membranous float or raft is secreted from the animal, like a crescentic piece of honey-comb, with the cells filled with air. The egg-sacs, which are not unlike those of the common Whelk, are attached beneath the float, and when the float is complete, and the egg-sacs full, the creature disengages it, and leaves the eggs to be hatched as it drifts about on the surface in the warmth and sunlight. The shells of *Ianthina* are common in the 'Globigerina Ooze.' They are not unfrequently cast up on the shore on the west coasts of Ireland and of Scotland, and even on the Shetland and Faroe Islands. They are not, however, inhabitants of the northern seas. They are drifted along and scattered about by the beneficent ameliorator, 'the Gulf-Stream.' (*Challenger*, Vol. I., p. 119.)



IANTHINA COMMUNIS.

"The *Ianthina*," says Dr. S. P. Woodward, "are gregarious in the open sea, where they are found in myriads, and feed on the small blue aculephæ (*Veella*). They are frequently drifted to the southern and western British shores, especially when the wind continues long from the S.W.; in Swansea Bay the animals have been found quite fresh. When handled they exude a violet fluid from beneath the margin of the mantle. In rough weather they are driven about and their floats broken or detached, in which state they are often met with. The capsules beneath the further end of the raft have been observed to be empty at a time when those in the middle contained young with fully-formed shells, and those near the animal were filled with eggs. They have no power of sinking or rising in the water. The raft, which is much too large to be withdrawn into the shell, is an extreme modification of the operculum." Six species have been described, from the Atlantic and Pacific.



IANTHINA AND ITS RAFT. (r, The Raft; e, the Egg-capsules.)

FAMILY XXII.—FISSURELLIDÆ.

The shell is conical and symmetrical, shaped like that of a Limpet, but with the apex curved, the front margin notched, or the top perforated; muscular scar semicircular, open in front. The animal has its eyes at the base of the tentacles, which are somewhat broad; the head has a short muzzle; the anal siphon occupies the notch in the shell in front, or passes through the hole in the summit of the shell; the teeth are like those of *Trochus*. It is a vegetable feeder.

Genus *Fissurella*.* "The Keyhole Limpet" has an oval conical shell, with a perforation in the top; the surface is cancellated with intersecting lines; in very young shells the apex is nearly spiral and the perforation in front of the apex, but the hole increases in size, and the summit gradually disappears. The *Fissurellæ* mostly inhabit the laminarian zone, but have a range from low water to fifty fathoms. One hundred and twenty species are described. They are cosmopolitan.

Genus *Macroschisma*. In this shell the perforation for the anal siphon is close to the hinder margin of the shell. The animal is far larger than its shell. It is found in the Philippines and West Australia.

Genus *Puncturella*. In this little shell the fissure is placed in front of the recurved apex; the shell is conical, and the surface is furrowed. Two species inhabit Greenland, Norway, and North America. It is also found at Tierra del Fuego, and both living and fossil in Britain.

Genus *Rimula*. The shell in *Rimula* resembles that in *Puncturella*, but is more oblong, and the perforation is near the anterior margin. Its habitat is the Philippines, and its range from low water to twenty-five fathoms.

Genus *Emarginula*.† This pretty little cancellated form has no hole in its shell, but the front margin has a deep slit for the anal siphon. Twenty-six species are found living from low water to ninety fathoms on the coasts of Britain, Norway, the Philippines, Australia, &c.

Genus *Parmophorus*.‡ Duck's-bill Limpet. The animal is very large compared with its shell, which

* Latin, diminutive of *fissura*, a slit.† Latin, *emarginata*, notched.‡ Greek, *parme*, a shield, and *phoreus*, a bearer.

is oblong, smooth, and white, but without perforation or notch, and is permanently covered by the mantle of the animal, which is black. It inhabits shallow water under stones. Ten species are described from the Red Sea, the Philippines, Australia, &c.

FAMILY XXIII.—NERITIDÆ.

The spire is very small and depressed, the shell is thick and round. The animal absorbs the internal portion of its shell to give room to the soft parts of its body; the aperture is half round, the columella is flattened, the operculum shelly, sub-spiral, and is articulated to the shell by a remarkable hinge-like process. The head of the animal is short and broad, the eye-stalks are prominent, the outside tentacles long and slender; the foot is oblong and triangular.

Genus *Nerita*. The shell has a horny epidermis, a thick outer lip, toothed within, and a broad and flat columella, the inner edge of which is straight and toothed. The Nerites are found in all the warm seas of the globe; they inhabit the littoral zone. One hundred and sixteen species have been described.

Genus *Neritina*. The fresh-water Nerites, like the marine *Neritas*, have a rather thick shell, with a sharp outer lip and a straight toothed inner one; the operculum is shelly, with a horny border, toothed on its straight side.

The Neritinae are small globular shells, ornamented with a great variety of black or purple bands and spots, covered with a polished horny epidermis. They are mostly confined to the fresh waters of warm regions. One species (*N. fluvialilis*) is found in British rivers and in the brackish water of the Baltic. Another extends its range into the brackish water of North American rivers; and the West Indian *N. viridis* and *meleagris* are found in the sea. (S. P. Woodward.) Another form is found in the brackish waters of India. *N. corona* (the Crowned Nerite), from Madagascar, is ornamented with a series of long tubercular spines. One hundred species are found living, and twenty fossil. "*Neritina sulcata* is found on the foliage of tall trees, many hundreds of yards from the river's bank in the Celebes." (Adams.)

The genus *Naricella* has a smooth, oblong, Limpet-like shell, with a small columella-shelf beneath; the operculum is very small and shelly; the shell is covered by a dark olive epidermis. The "Boat-shells," as they are called, inhabit fresh waters, adhering to stones and water-plants. Twenty-four species are described.

FAMILY XXIV.—PATELLIDÆ.

The Limpets have conical shells, the apex of which is turned towards the front; they have a horseshoe-shaped muscular scar inside. The head is provided with tentacles having the eyes at their outer bases, the foot is as large as the edge of the shell, the gills are concealed at the back of the head, the tongue is ribbon-like and of great length.

Genus *Patella*.* In *Patella* the shell is usually oval and tent-shaped, the interior smooth, but not pearly, the outside rough or having radiating ribs, the margin sometimes spiny.

The tongue of the Limpet is longer than its shell; it has 160 rows of teeth, twelve in each row, or 1,920 in all. *Patella variegata*, two inches and a quarter long, has a tongue twelve inches and a half long. (Blanford.) The Limpets inhabit rocks between tide-marks, and are left dry twice every day. They adhere firmly like a sucker to the rock, and it is difficult to detach them without breaking their shells. They always return to the same spot after feeding, and the place where they rest, even on very hard rock, is found to be worn into a smooth concavity beneath the foot of the animal, and the margin of the shell exactly fits the inequalities of the surrounding surface. The Limpets are all vegetable feeders. One hundred living species have been described. They are world-wide in distribution. The *Patella*, or Rock Limpet, is much used by fishermen for bait. On the coast of Berwickshire nearly twelve millions have been collected yearly, until their numbers are so decreased that collecting them has become tedious. In the north of Ireland they are used for human food, especially in seasons of scarcity. Many tons' weight are collected annually near the town of Larne alone. (Patterson.)

The "Oyster-catcher" (*Haematopus ostralegus*), a well-known sea-shore bird, does not subsist upon the Oyster, as its name implies, but chiefly upon the Rock Limpet. The adroitness

* Latin, *patella*, a dish.

which he displays in undermining these far exceeds the rapidity of the most practised oyster-opener at a London fishmonger's shop.

On the western coast of South America there is a Limpet which attains the diameter of a foot, and is used by the natives as a basin.

FAMILY XXV.—DENTALIADÆ.

Genus *Dentalium*, "Tooth-shells." The shell is like a curved tube, open at each end, gradually increasing in size from the posterior to the anterior end; the surface is either smooth or ribbed longitudinally; the mouth is round (not contracted at the aperture, like the genus *Ditropa*, which is an annelid). The animal is attached to its shell near the smaller end; the head is rudimentary, the eyes and tentacles are wanting, the mouth is fringed, the foot is pointed. The *Dentalia* are all animal feeders, devouring foraminifera and minute bivalves; they bury themselves in the mud, and range in depth from ten to 100 fathoms. Their distribution is nearly cosmopolitan. Thirty living species are known.

In the Cavern of Bruniquel, Valley of the Aveyron, Department of Tarn-et-Garonne, several shells have been found, evidently collected and used by the pre-historic occupants as ornaments. These included *Dentalium*, *Natica*, *Nassa*, *Pectunculus*, *Scaloria*, *Voluta*, and *Cypræa*, several of which had been perforated.

Corresponding to the Cowry currency of Asia and Africa is the American Ioqua, or *Dentalium*, a shell found chiefly at the entrance of the Strait of De Fuca, and employed both for ornament and money. The Chinooks and other Indians of the Northern Pacific coast wear long strings of Ioqua shells as necklaces and fringes to their robes. These have a value assigned to them, increasing in proportion to their size, which varies from about an inch and a half to upwards of two inches in length. Mr. Paul Kane writes:—"A great trade

is carried on among all the tribes in the neighbourhood of Vancouver Island through the medium of these shells. Forty shells of the standard size, extending a fathom's length, are equal in value to a beaver's skin; but if shells can be found so far in excess of the ordinary standard that thirty-nine are long enough to make a fathom, they are worth two beavers' skins; and so on, increasing in value one beaver skin for every shell less than the first number."



DENTALIUM
ELEPHANTINUM.



CHITON MAGNIFICUS.

FAMILY XXVI.—CHITONIDÆ.

Genus *Chiton** (Linnaeus). Unlike the other Mollusca already described, the shell of *Chiton* is made up of eight imbricated plates, fixed transversely on the back of the animal, which enable it, when caught, to roll itself up like a Woodlouse or an Armadillo; the border of the mantle is bare, or covered with minute plates, hairs, or spines. Like the Limpets, the Chitons have a broad creeping disc; they have a long series of lingual teeth, but no eyes or tentacles. More than two hundred species occur, living all over the world, from low water to a hundred fathoms.

ORDER II.—PULMONIFERA.†

In this order are placed all the air-breathing Snails. Many of them have forms externally similar to the Sea Snails, whose tribes we have already enumerated; but they differ in this essential character: that whereas the BRANCHIFERA carry on their respiration in water by gills or membranes (like fishes), and, as a rule, lead an aquatic existence, the PULMONIFERA admit *air* into their breathing chamber, which is lined with finely-branching vessels, and is, in fact, a simple form of lung; and they mostly lead a terrestrial existence.

In the Pulmonifera, or Air-breathing Snails, provision is made for the admission of air directly into a respiratory chamber (*m*) formed by the mantle. In some of the Slugs this is placed at the hinder extremity of the body, as in *Testacella*, in the others at one side of the mantle; and in the Garden Snail the aperture is nearly in front, beneath the mouth of the shell (*n*). The mouth (*a*) has a

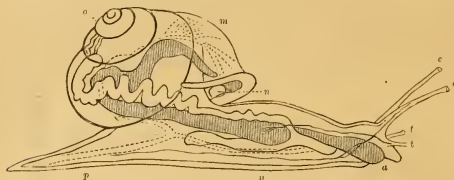
* Greek, *chiton*, a coat of mail.

† Latin, *pulmo*, a lung; and *fero*, I bear or carry.

horny upper jaw, and is also provided with an *odontophore*, bearing an excellent set of lingual teeth. (See p. 222.)

The air-breathing Snails are, as a rule, vegetable feeders, and form two great divisions.

*Division a. INOPERCULATA,** or Snails without an operculum. This division embraces a great proportion of the terrestrial Snails. They usually have well-developed shells, sufficiently large to conceal the entire animal; and although, as a rule, they flourish most in warm humid regions, where vegetation is abundant, they are found even in very dry and arid regions, and are able to survive under conditions which would at first sight appear fatal to any soft-bodied mollusc.



ANATOMY OF THE COMMON GARDEN SNAIL.

a, mouth; p, foot; e, eye; n, Of the opening into Pulmonary Cavity; m, Branchia; t, Tentacles; s, Shell not Ovaries; the Shaded Part is the Stomach and Intestines; the Single Lines are Nerves, the Dotted Lines Blood-vessels.

coloured the tablet with his slime in his endeavours to free himself. Failing to do this, he had again retired, closing the mouth of his shell with the glistening film which all Snails make during hibernation (called an epiphragm †). This attracted attention, and Dr. Baird having immersed the Snail-shell in tepid water, the desert wanderer crawled out and walked about, and partook of a lettuce-leaf, and was for a long time the cynosure of an admiring circle of visitors.

In this division are also placed those apparently helpless, but exceedingly wide-awake pests of our gardens, the *Limacide*, or Slugs (most of which are quite naked, though a few have a tiny rudimentary shell, often internal).

It also includes a family called *Oncidiadæ*, another named *Limacidæ* (in which are many of our Pond Snails), and a fifth family, the *Auriculidæ*, inhabiting salt marshes in the tropics.

FAMILY XXVII.—HELICIDÆ.

The Land Snails have a well-developed external shell, into which the entire animal can be withdrawn. These "snail-houses" are exceedingly varied in the form of their spirals, and the whorls are frequently decorated with bright bands of colour; the mouth is often curiously twisted and toothed within. Some show periodic growths. In cold countries Snails hibernate in winter; in hot countries they sleep during the dry season, coming out with the first rain. In both cases the Snail (having no operculum to his shell) makes an epiphragm of hardened mucus, sometimes strengthened with a thin deposit of lime. In this temporary lid a small aperture is left to breathe through, the rest being carefully closed.

The Snail has a head with four cylindrical, retractile tentacles, of which the upper pair are the longest, and have the eyes at their summits. The breathing opening is on the right side, beneath the margin of the shell. The foot is very distinct, and usually elongated. The mouth has a strong horny upper mandible, and a broad oblong tongue armed with numerous rows of small teeth.

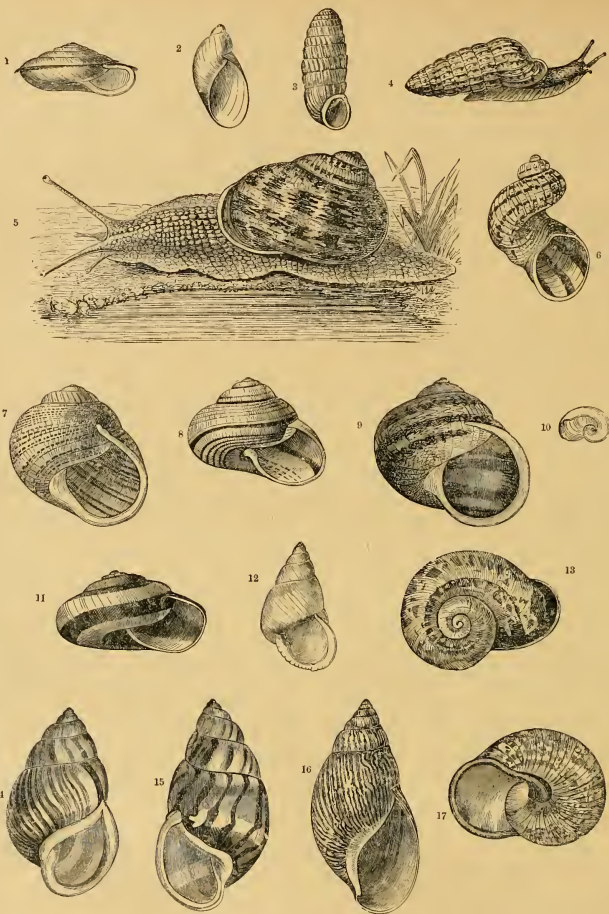
Genus *Helix*. The shells of the Helices vary in form, but are mostly either umbilicated, perforate or imperforate; some are discoidal, or globosely depressed, or conoidal. The aperture also varies greatly in form.

In *Gibbus lyonetti*, from Mauritius, the shell, after forming five ordinary convolutions, suddenly makes a complete double in its growth, and remains hump-backed for the rest of its

* Latin, *in*, without; *operculum*, a lid.

† Greek, *epi*, upon; *phragma*, a partition.

Thus, for example, my late colleague, Dr. Baird, F.R.S., of the Zoological Department, British Museum, records (in the *Annals and Mag. Nat. Hist.* for 1850) that, having received some specimens of the "Desert Snail" from Egypt, he fixed them with gum mastic to a tablet on 25th March, 1846; on 7th March, 1850, it was found that the Snail had come out of his shell, and had dis-



LAND SNAILS.

- 1, *Helix Mackenzii*; 2, *Succinea putris*; 3, 4, *Pupa uva*; 5, *Helix aspersa*; 6, *H. aspersa*, var. *scalaris*; 7, *H. undulata*; 8, *H. Stuebeli*; 9, *H. aspersa*; 10, *Vitrina fasciata*; 11, *H. citrina*; 12, *H. transluceida*; 13, 17, *H. Waltoni*; 14, 15, *Bulinus sulcatus*; 16, *Achatina zebra*.

days. The still more eccentric Land Snail, *Helix* (*Anastoma*) *globulus*, from Brazil, after growing like the ordinary *Helix hortensis*, or *arbutorum*, suddenly pulls up, and, twisting his mouth up tight, produces the aperture on a plane with the spire.

Many of the Land Snails, not furnished with *opercula*, fortify the entrance to their shell by secreting a number of shelly plates, or teeth, around the aperture, so as to lead one to marvel how the occupant of the shell ever managed to get in or out of his own house, and still more how the eggs were excluded.

Snails are world-wide in their distribution, numbering more than 1,600 species. Their northern limits extend as far as trees grow, and south to Tierra del Fuego. Their greatest development is in the warm and humid regions of the globe. They attain in the Andes to an elevation of 11,000 feet, and to 8,000 feet in Ceylon. About fifty species of *Helix* are found fossil in the Tertiary rocks. The Snails found on oceanic islands are mostly peculiar.

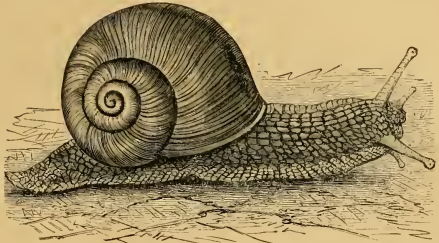
The Land Snails, such as the *Helix arbutorum* and *H. aspersa*, are the favourite food of the Blackbird and Thrush, and a smaller species of *Helix*, common on sandy pastures, is said by Patterson to be eaten in vast numbers by the sheep when grazing, and to form a very fattening kind of food. Another Land Snail (*Helix pomatia*) was highly esteemed by the Romans, who fattened them as articles of food. They are still found abundantly in many localities in the south of England, especially about the sites of old Roman villas in Gloucestershire. They were at one time appreciated as an article of food, and when boiled in spring water, and seasoned with oil, salt, and pepper, they make a dainty dish. The French still eat them extensively, as do also the poorer classes in Spain and Italy; the Brazilians also eat Land Snails. Every one who visits Paris should taste a dish of Snails; they are most delicious.

In summer and winter Land Snails cease to grow. The Snails of the first year, hatched in the spring, usually attain half their growth in the autumn of the same year, and their maturity in the following spring. There is always a stronger line of growth or conspicuous mark on banded and Garden Snails, and in some a rib inside strengthens the rim of the half-grown shell.

Genus *Vitrina*, "Glass-shell." The shell is very thin, the whorls are few, the last is large, with a wide aperture and a thin lip. "In its geographical distribution, the genus *Vitrina* is found in every part of the globe, the species being most numerous north of the equator. They live in moist situations, among loose earth, stones, grass, and moss. They are very lively, crawling constantly about, and, when touched, will sometimes jump several inches from the ground. The tail of the animal is obliquely truncated, and the edge-teeth of the tongue are sharp-pointed." (Adams.)

Genus *Succinea*, "Amber Snail." The animal is large in proportion to its shell; its foot is broad, and the tentacles are short and thick; its shell is like that of *Limnaea* in shape, having a small spiral, but a large aperture; its lingual teeth are like *Helix*. *Succinea putris* has fifty rows of teeth, sixty-five teeth in a row. These Snails inhabit damp places, but rarely enter the water. There are sixty-eight living species in almost all parts of the world.

Genus *Bulinus*. This is a turreted shell, with an ear-shaped aperture, usually simple and smooth, but sometimes toothed; the outer lip often thickened at the border. The animal is like *Helix*. The great *Bulinus ovatus*, from South America, is six inches long; it is eaten in Rio. It deposits its eggs among dead leaves. They have a calcareous shell, and when hatched the young are one inch in length. Six hundred and fifty species, of world-wide distribution, are described.



HELIX POMATIA.

Genus *Achatina*, "Agate-shell." The shell is like that of *Bulinus* in form, with a twisted columella, truncated in front, with an oval aperture; the lip is sharp. The great African *Achatina* is the largest land-shell known, being eight inches in length; the eggs are more than an inch long; they have a calcareous shell. They are found in all quarters of the globe. One hundred and twenty species are found living, and fourteen fossil. They are said to



LINGUAL TEETH OF *ACHATINA FULICA*. (After S. P. Woodward.)

l, Lateral Row; c, Central Row.

burrow in the earth, and to be found at roots of garden bulbs. An *Achatina* kept in confinement refused vegetable food, but ate another Snail.

In addition to the variously disposed jaws, or cutting-plates of a chitinous or calcareous substance with which nearly all Land and Sea Snails and Cuttle-fishes are furnished, they possess a most characteristic buccal, or mouth apparatus—the "odontophore"* (tooth-bearer), commonly called the "tongue," which is attached to the floor of the mouth. It is partly fibrous, and partly cartilaginous, and is provided with special muscles. The external layer, called the radula, is armed with tooth-like processes (see woodcuts), arranged in one or many series, and additions are being constantly made to its posterior end, which is lodged in a sac. The teeth are thus replaced from behind as fast as they are worn away by friction against the food which they rasp, at the anterior end of the tongue. The muscles are so arranged as to cause this wonderful apparatus to travel, backwards and forwards, over the ends of the supporting cartilages of the mouth, in the fashion of a chain-saw, and thus to rasp any substance to which the teeth may be applied. The whole apparatus is also capable of being protracted or retracted, and may thus give to the extremity of the radula a licking motion, which is quite distinct from the chain-saw movement. Salivary glands are also generally present. (Huxley.)

Genus *Pupa*, "Chrysalis-shell."† The shells of this genus are very small, ovoid, with an obtuse apex, whorls inflated, broadest in mid-growth, narrower in later growth; the mouth is often contracted, and sometimes thickened and toothed; the surface of the shell is closely ribbed with straight fine ridges. The foot is short and pointed behind, the lower tentacles short. *Pupa* has a world-wide distribution; it is common in Europe, North America, and Africa, under stones and in crevices of rocks and trees, or among wet moss, chiefly in chalky districts.

Genus *Cylindrella*, "Cylinder-shell." The shells of this genus are either pupiform or cylindrical, many-whorled, sometimes left-handed; in the adult shell the apex is usually lost, a septum or partition being formed within to cover the hole. Shells that have lost their apex are said to be decollated.‡ The aperture is round and expanded. The animal is like *Clausilia*, with a short foot, and the lower tentacles small. Fifty species are known in the West Indies and America.

Genus *Clausilia*.§ These little shells are of a brown colour, with a tall spire swollen in the middle: the whorls are transversely striated; the mouth has a thickened contracted lip, with two shelly plates on the inner lip; all the species are left-handed. Nearly 400 are known in Europe and Asia.

FAMILY XXVIII.—LIMACIDÆ (SLUGS).

The Slugs have no true shell; the head and tentacles are retractile, the respiratory and visceral organs being incorporated within the contractile body of the animal, which differs from the Snails in being straight, not spiral. The first indication of a shell takes the form of a small shield-like plate, covering the breathing organs. This rudimentary shell is usually internal; in *Testacella* it is external.

"The *Limacidae* shun the light of day, rarely indulging their voracious appetites, except at night. They inhabit gardens and roadside hedges in damp places, and congregate in cellars and outhouses and under planks and stones, around old walls, pumps, and wells. These remarks apply chiefly to the genera *Arion*, *Geomolux*, and *Limax*, which feed on vegetable matter, though not entirely abstaining from flesh. *Testacella* burrows into the ground to the depth of from two to three feet, and feeds, or

* Snails are hence called ODONTOPHORA by some authors.

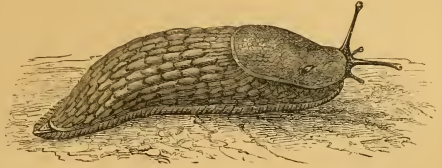
† The oldest air-breathing snails have been found by Sir W. Dawson in the Coal Measures of Nova Scotia, viz., *Pupa vetusta* and *P. vermilionensis*, *Darsonella meekii*, and *Zonites priscus*.

‡ Latin, *de*, without; *collis*, a top.

§ Latin, *claustrum*, a closed place, in reference to the mouth of the shell.

rather gorges, upon worms. The feebleness of the shell-producing functions in the *Limacidae* is largely compensated by the faculty of secreting mucus of a particularly viscid kind from all parts of the body. The Slug will lower itself to the ground from a tree or shrub—even from a shelf when brought into a room—by the mere accumulation of mucus at the extremity of the tail hardening into a gelatinous thread. The animal functions are not suspended during hibernation and at other periods, as in the Snail; and the animal is at all times more tenacious of life. The continued secretion of mucus is necessary to the Slug's existence. When this faculty ceases and the integuments dry, the animal dies." (Reeve.)

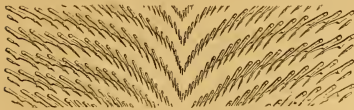
Genus *Limax*. *Limax* has the foot pointed behind and keeled throughout the back; the mantle is shield-shaped, and placed on the anterior portion of the back; the breathing orifice is on the right side, near the hinder margin of the mantle. The creeping-disc extends the whole length of the animal, but they frequently lift up their heads like the Snail, and move their tentacles in search of objects above them. When alarmed, they withdraw the head beneath the mantle and contract the foot. In dry weather and in winter they bury themselves in the ground. Twenty-two species are found living in Europe and the Canary Islands.



SLUG. (*ARION ATER*, "BLACK ARION.")

Genus *Arion*. The Slugs of this genus are distinguished from those of *Limax* proper by the presence of a pore or gland, for the more copious secretion of mucus, at the extremity of the tail, and in having the pulmonary sac and overlapping shield nearer the head, with the respiratory orifice in front. The shield has no internally developed shell, its place being occupied by merely a few calcareous grains, which are sometimes isolated, sometimes aggregated into a rude irregular mass. The body is enveloped by integuments of considerable density, rising into wrinkle-like tuberosities or leaflets, and there is no dorsal keel. (Reeve.) They lay from seventy to one hundred eggs between May and September, which are twenty to forty days in hatching, and attain their full growth in a year. Six species are found in Europe and Africa.

Genus *Parmacella*.* The *Parmacella* has a large foot, pointed behind; the mantle is small and shield-like in the middle of the back, partially concealing the small oblong and nearly flat shell, which has a sub-spiral apex. There are seven species, found in South Europe, the Canary Islands, and India.



LINGUAL TEETH OF *TESTACELLA HALIOTIDES*.
(After a Drawing by S. P. Woodward.)

Genus *Testacella*. The shell in *Testacella* is small and ear-shaped, and placed at the hinder extremity of the body, which is elongated, broadest behind, tapering towards the small head. *Testacella* is subterranean in its habits, feeding on

earthworms, and visiting the surface only at night. During the winter and dry weather the *Testacella* forms a sort of cocoon in the ground by the exudation of its mucus. If this cell is broken the animal may be seen completely shrouded in its thin opaque white mantle, which rapidly contracts until it extends but a little way beyond the margin of the shell. *Testacella* has been found in gardens in London, at Norwich, and in a field in Devizes. Three species are known in the South of Europe, the Canary Islands, and Britain.

FAMILY XXIX.—ONCIDIADÆ.

The animal is without a shell, and completely covered by coriaceous mantle.

Genus *Oncidium*.† The characters of this genus are, animal tuberculated, oblong, convex, with

* Greek, *parme*, a shield.

† From Greek, *onkos*, a tubercule.

two retractile tentacles, bearing the eyes; more than seventy rows of lingual teeth, 109 in a row, *i.e.*, a single symmetrical tooth in the centre, and fifty-four lateral teeth on each side.

The *Oncidia* are found living on aquatic plants in marshes in the warmer parts of the world; others frequent sea-shores on rocks near the surface of the sea, ascending and descending as the tide rises and falls. Sixteen species are found in Britain, the Red Sea, Mediterranean, &c.

Genus *Vaginulus*. This animal is like *Oncidium*, but with four tentacles, the lower pair of which is short and bifid. *Vaginulus* inhabits forests, living amongst decayed wood and under leaves. Six species are known in the West Indies, India, South America, and the Philippines.

FAMILY XXX.—LIMNÆIDÆ.

The Limnæidæ, or Pond Snails, are widely distributed over the globe, and are plentiful in individuals, but the species are few, and they are far less varied in the Old World than in the New. We have almost as many species in Britain as exist in all Europe.

Genus *Limnaea*.* The shell is ovately turreted, thin, horny; spire elongated and sharply pointed; body-whorl ventricose; aperture large. The animal has a broad short head and flattened tentacles; eyes near the inner bases. The *Limnaea* inhabit fresh water, and feed chiefly on decaying leaves; they deposit their spawn in oblong transparent masses on water-plants and stones. They glide beneath the surface of the water, shell downwards, and hibernate in the mud. Fifty species are found living in Europe, Madeira, India, China, and North America.

The genus *Chilina* has a thin oval shell, marked with wavy bands or dark spots; columella plicated and thickened. Fourteen species occur in South America in running water.

The shell of *Physa* is a left-handed spiral; the aperture is rounded in front; the mantle has an expanded margin, bordered with long filaments. Twenty species occur in America, Europe, South Africa, India, and the Philippines.

Genus *Aureglus*, "River Limpet." The shell is Limpet-shaped and thin; the apex left-handed. The animal is like *Limnaea*. Fourteen species are found in running streams, attached to stones and aquatic plants in Europe, North and South America.

Genus *Gundlachia*. The Shell is thin, obliquely conic; two-thirds of base closed by a flat horizontal plate. It is found in fresh water in Cuba.

Genus *Planorbis*. The shell in *Planorbis* is discoidal: the apex is sunk in the nucleus of the coil; whorls three to seven in number, smooth or striated, sometimes keeled along the border. The body is slender, the head obtuse; tentacles long and bristle-like, with the eyes at their bases; foot small and narrow. "*Planorbis* inhabits all kinds of stagnant pools and ditches and gently running brooks, chiefly adhering to flags and other water-plants. When left dry in the bed of a stream by retreating water, the animal encloses itself within the shell by an epiphragm." (Reeve.) Sixty species occur in Europe, North America, India, and China. It is common in England.

FAMILY XXXI.—AURICULIDÆ.

The *Auriculidæ* were long regarded as marine shells; they frequent salt marshes, damp hollows, and places overflowed by the sea. They have a spiral shell coated with a horny epidermis; the body-whorl is large, the spire very short; the aperture ear-shaped; the columella plaited. The animal absorbs the internal column of its shell. It has a broad short head with two tentacles, the eyes behind them; orifices as in Snails.

Genus *Auricula*.† The shell has an obtuse spire, covered with a dark epidermis; outer lip expanded and thickened. Fifty species are found living within the tropics, the Philippines, Celebes, and Peru.

Genus *Carychium*. This small mollusc has an oblong, finely striated shell; the aperture oval and toothed. It has two blunt cylindrical tentacles; the eyes are black and near their bases. One species, from the caverns of Carniola, is blind.

* *Limnaea*, Greek, marshy.

† Latin, *auricula*, little ear.



LIMNÆA STAGNALIS.



PHYSA CAS-
TANEA.

Genus *Siphonaria*.* The shell is flattened and tent-shaped, like *Patella*, rugose externally, divided on the right side by a deep siphonal groove, which makes a slight projection on the margin. The *Siphonaria* live on rocks between the tide-marks. Thirty species are known, almost world-wide.

Division b. OPERCULATA.—Like the preceding division of Land Snails, these are all air-breathers, but they differ in possessing a shelly or horny operculum. They are exceedingly like Periwinkles in appearance. The pulmonary cavity is at the back of the neck, and quite open.

FAMILY XXXII.—CYCLOSTOMIDÆ.

The eyes are slightly prominent on the outer side of tentacles, which are retractile; the foot is elongated, the muzzle long and truncated, mouth simple, operculum spiral.

In the genus *Cyclostoma*, the shell is ovately turbinated, solid, covered with spiral ridges, and minutely reticulated. *Cyclostoma cleyanis* may be collected in great abundance in the spring of the year in Chalk districts. More than eighty species have been described from South Europe, Africa, and Madagascar.

Many of the land shells are very fine and costly, but the names of species, which are worth from £1 to £3, when in good condition, are far too many to be enumerated. Novelties realise higher prices, like the *Cyclostoma de burghar*, which was worth £5 when first brought from Madagascar by Madame Ida Pfeiffer—poor restless soul! A few Snail-shells were all she obtained in compensation for a fever, which terminated her wanderings and her life.

In the genus *Cyclophorus** the characters are, animal with a short obtuse muzzle, tentacles long, pointed, and slender, foot broad, shell rounded, spire depressed, umbilicate, aperture circular, lip continuous, operculum horny. There are nearly 100 species, which are found in India, the Philippines, &c.

Genus *Pupina*. This curious little *Pupa*-like shell has a circular aperture and a thickened lip, notched before and behind; the operculum is membranous and spiral. Eight species are found in the Philippines, New Guinea, &c.



CYCLOPHORUS, AN OPERCULATED LAND SNAIL.

FAMILY XXXIII.—HELICINIDÆ.

Genus *Helicina*. The shell is flattened, globular; lip simple, expanded; operculum shelly or membranous. The animal resembles *Cyclophorus*. One hundred and fifty species are met with in the West Indies, Philippines, Central America, Pacific Islands, &c.

Genus *Stoastoma*† All the nineteen species of *Stoastoma* proper are sculptured with spiral lines, and inhabit the island of Jamaica.

FAMILY XXXIV.—ACICULIDÆ.

Genus *Acicula*. The shell is minute and slender, operculum hyaline. *A. fusca* inhabits low marshy situations at the roots of grass. Five species are described as occurring in Britain, Europe, and Vanicoro.

Genus *Gromelania*. The shell is minute, turreted; whorls few, rapidly enlarging; aperture simple, expanded. Twenty-one species are found in Jamaica.

ORDER III.—OPISTHOBRANCHIATA.‡

In this division the animal's gills are not contained in a special cavity, but are exposed on the back and sides towards the rear of the body. When alarmed or removed from their native element, they retract their gills and tentacles, and present the appearance of a lump of jelly.

Division a. TECTIBRANCHIATA. The shell is rudimentary, and sometimes wanting; the gills are covered either by the shell or mantle.

FAMILY XXXV.—TORNATELLIDÆ.

Genus *Tornatella*. The shell is external, solid, spiral, many-whorled; outer lip sharp; aperture rounded in front, long, and narrow; columella strongly folded; operculum horny, elliptical. The head is short and notched in front; it has two flattened tentacular lobes, with small sessile eyes

* Greek, *cyelos*, a circle, and *phoreus*, a bearer.

† Greek, *stoa*, pillared; *stoma*, mouth.

‡ Greek, *opisthen*, behind; *branchia*, gills.

near their bases ; the foot is oblong. Sixteen living species have been described. They inhabit deep water in the Red Sea, the Philippines, Japan, &c.

Genus *Ringicula*. Four species are found living in the Mediterranean, India, &c.

Genus *Tornatina*. The shell has a conspicuous spire, fusiform or cylindrical ; suture channelled, columella plaited ; head of animal broad, rounded in front, with triangular tentacular lobes ; eyes at their base ; foot truncated in front. *Tornatina* is found on sandy bottoms at a depth of thirty fathoms. Fifteen species occur, very widely distributed over the world.

FAMILY XXXVI.—BULLIDÆ.

The shell is thin, convoluted, cylindrical, or globular ; spire concealed, aperture long ; lip sharp, without operculum. The shell is more or less internal, being covered by the lobes of the mantle of the animal. The *Bullidæ* are animal feeders ; the gizzard is provided with calcareous plates, which assist in the process of digestion.

Genus *Bulla*, the "Bubble-shell." The shell in *Bulla* has no spire ; the aperture is as long as the shell, and rounded at the ends ; the tentacular lobes form with the head a flattened disc, truncated in front, lobed behind. *Bulla* is found living from low water to thirty fathoms. Fifty widely-distributed species have been described.

In the genus *Scaphander** the characters are, shell convolute ; spire concealed ; aperture expanded, oblong ; surface spirally striated ; animal blind ; head oblong ; foot broad and short ; the lobes of the mantle partially envelop the shell. Five species occur recent, in Britain, Norway, the Mediterranean, &c., living at a depth of fifty fathoms.

Genus *Philine*. The animal is like a Slug ; mantle entirely covering the shell ; head oblong ; blind ; foot broad. It is found living in Britain, Norway, the West Indies, &c.

The genus *Doridium* has only a rudimentary membranous shell, covered by the mantle.

The other remaining genus (*Gastropteron*) is shell-less.

FAMILY XXXVII.—APLYSIADÆ.

Genus *Aplysia*, the "Sea-hare," has a long neck ; the head has four tentacles, the inner pair ear-like, with the eyes at their bases ; the shell is translucent, oblong, rudimentary ; it is covered by the mantle. "The Sea-hares live chiefly on seaweed, but also devour animal substances. They inhabit the laminarian zone. When molested they discharge a violet fluid from the edge of the internal surface of the mantle." (Goodsir.) Forty species are found in Britain, Norway, West Indies, &c.



SHELL OF AP-
LYSIA INCA.

Genus *Dolabella*. The shell is triangular, hard, with a curved apex. The animal is like *Aplysia*.

Twelve species are found living in the Mediterranean, Ceylon, Sandwich Islands, &c.

Genus *Notarcus*. The animal is shell-less. Four species are found in the Mediterranean, Red Sea, and the West Indies.

The genus *Lobiger* has the shell exposed on the middle of the back, covering the plume-like gill.



APLYSIA INCA.

FAMILY XXXVIII.—PLEUROBRANCHIDÆ.

In the genus *Pleurobranchus*† the shell is quite covered by the mantle ; it is large, slightly convex and flexible, nucleus sub-spiral ; head with two grooved tentacles, eyes at their bases ; foot large, separated from the mantle by a furrow ; a single gill is placed on the right side between the mantle and the foot. Twenty species are met with living in Britain, Norway, and the Mediterranean, &c.

Genus *Umbrella*. The "Chinese Umbrella-shell" has a small depressed Limpet-like shell, marked by concentric lines of growth ; the animal has a very large foot, deeply notched in front ; the tentacles are ear-shaped. Three species are found in the Mediterranean, &c.

The genus *Tylodina*, of which there are three species living, is very like the preceding. It occurs in the Mediterranean, Norway, &c.

* Greek, *scapha*, a boat, and *aner*, a man.

† Greek, *pleura*, the side, and *branchia*, the gills.

FAMILY XXXIX.—PHYLLIDIDÆ.

In the genera *Phyllidia* and *Diphyllidia* the animal is shell-less, the internal organs being covered by the mantle; the gills form a series on both sides of the body, between the foot and the mantle. They are found in Britain, Norway, and the Red Sea.

Division b. NUDIBRANCHIATA.—The Sea Slugs are found on all coasts where the bottom is firm or rocky, from between tide-marks to a depth of fifty fathoms. A few species are pelagic, crawling on the stems and fronds of floating seaweed. They have been found in the Icy Sea and in the Sea of Okhotsk, whilst in tropical and southern seas they are abundant. The animal is destitute of a shell, except in the embryo state. The branchiæ are always external on the back and sides.

FAMILY XL.—DORIDÆ (SEA-LEMONS).

The gills are plume-like, and placed in a circle in the middle of the back. Genera: *Doris*, *Goniodoris*, *Triopa*, *Egirus*, *Thecatera*, *Polycera*, *Idalia*, *Ancula*, and *Ceratosoma*.

FAMILY XLI.—TRITONIADÆ.

The gills in this family are arranged along the sides of the back; the tentacles are retractile into sheaths. Genera: *Tritonia*, *Scyllæa*, *Tethys*, *Bornello*, *Dendronotus*, *Doto*, *Melibeia*, and *Lomanctus*.

FAMILY XLII.—ÆOLIDÆ.

In this family the tentacles have no sheaths and are non-retractile; the gills are placed on the sides. Genera: *Æolis*, *Glaucus*, *Fiona*, *Embletonia*, *Proctonotus*, *Antiope*, *Hermæa*, *Alderia*.

FAMILY XLIII.—PHYLLIRHOIDÆ.

These are pelagic footless Sea Slugs, swimming with a fin-like tail. They have two dorsal tentacles and no gills. Genus: *Phyllirhoe*.

FAMILY XLIV.—ELYSIADÆ.

The animal is Slug-like, without distinct mantle or breathing organs; the surface of the body is ciliated. Genera: *Elysia*, *Acteonia*, *Uenia*, *Limapontia*.

ORDER IV.—NUCLEOBRANCHIATA.

This order is so called because the animals contained in it have the respiratory and digestive organs arranged in a sort of nucleus on the posterior part of the back. All the members are pelagic, swimming on the surface of the sea; still, they are entitled to a place in the class. They swim rapidly by vigorous movements of their fin-like tails or by a fan-shaped ventral fin, and they can adhere to objects by a small sucker placed on the margin of the latter.

FAMILY XLV.—FIROLIDÆ.

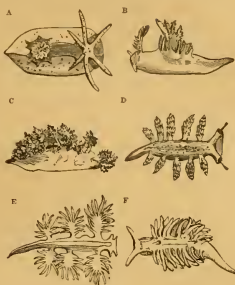
Genus *Firola*. The animal is fusiform, with a long slender head; fin narrow at the base, having a small sucker; eyes black and distinct. Eight species are known in the Atlantic, Mediterranean, &c.



CARINARIA CYMBIUM.

d, the proboscis; *t*, the tentacles; *f*, the foot; *s*, the shell; *g*, the gills, or branchiæ; *d*, the disc.

Genus *Carinaria*. The body is large and translucent, head cylindrical, tentacles slender, ventral fin rounded, tail laterally compressed; the gills are numerous, and covered beneath by a delicate hyaline. The shell is Limpet-shaped, with a sub-spiral apex. "The Heteropoda are very close to the Gasteropoda, and in most modern works on zoology they are associated with them as a sub-class. They are entirely pelagic, and as it is only under peculiar circumstances that one can stop the ship in mid-ocean and hunt for them, they are little known. One



A, IDALIA; B, MIRANDA; C, DENDRONOTUS; D, DOTO; E, HERMÆA; F, GLAUCUS.

or two of their shells are met with in collections; one especially, *Carinaria*, a beautiful little glassy boat, which one would take at first for some form of Paper Nautilus. The shell of *Carinaria* gives no idea, however, of the form of the animal which, with one or two allied genera—such as *Pterotrachea* and *Firoloides*, which do not produce shells at all—is sometimes abundant in calm weather on the surface of the warm seas. The shell hangs below the animal, connected with it by a kind of neck, and is merely meant for the protection of some very vital organs, including the heart, the gills, and the liver. The remainder of the animal is ten times the size of the shell, and forms a large sac, usually gelatinous and very transparent, often dotted over with purple pigment spots. The front of the sac is drawn out into a long, singularly-formed snout, and near it there are bright, well-marked eyes, and a pair of feelers. The posterior part of the sac is produced into a fin-like tail. Along the upper middle line of the animal, in the position in which it swims in the water, the part corresponding with the ‘foot’ in ordinary shell-fish is raised into a high crest-like fin. The bodies of these creatures are large, some of them not less than five or six inches in length, but, like most free-floating animals, they are very soft, formed mainly of ‘connective tissue,’ with little in it but sea-water. In this way their bulk is greatly increased without materially adding to their weight, and they weigh little more than an equal bulk of sea-water, and require little exertion to float or swim.

“One curious result of this transparency is that we can see through the outer wall, in the most wonderful detail, all the internal arrangements—the nervous centres, with the complicated organs of sense, the heart, with its pulsating chambers, and the blood following its course through the system and through the gills, the alimentary canal, and all its accessory glands. The Heteropoda are probably the most highly-organised group in which such transparency exists.

“The shells of *Carinaria* are rare in the Globigerina Ooze; but two small spiral shells, belonging to animals of the *Atlanta peronii* and *Orygyrus keraudrenii*, are sometimes in such numbers as to have a sensible effect in adding to the formation. Although Heteropod shells of the present day are insignificant in size, they played a much more important rôle in early times, for there seems little doubt that the great shells of the genera *Euomphalus* and *Bellerophon*, which sometimes go far to make up whole beds of limestone of the Silurian and Carboniferous periods, are to be referred to this group.”*

The *Carinariæ* are found in the warmer parts of the Atlantic and Indian Oceans. They feed on Acalaphæ and Pteropods. Five species are described.

Genus *Cardiopoda* has a minute cartilaginous shell; animal like *Carinaria*; habitat, the Atlantic Ocean. Five species are known.

FAMILY XLVI.—ATLANTIDÆ.

In the genus *Atlanta* the shell is small and glassy, with a prominent keel; the aperture is narrow and deeply notched. Fifteen species occur in the warmer parts of the Atlantic.

CLASS III.—PTEROPODA.

The *Pteropoda*, or “Wing-shells,” are a small group of animals, whose entire life is passed in the open sea, far away from any shelter, save what is afforded by the floating Gulf-weed, and whose organisation is specially adapted to that sphere of existence. In appearance and habits they strikingly resemble the fry of the ordinary Sea Snails, swimming like them by the vigorous flappings of a pair of fins. To the naturalist ashore they are almost unknown, but the voyager on the great ocean meets with them where there is little else to arrest his attention, and marvels at their delicate forms and almost incredible numbers. They swarm in the tropics, and are no less abundant in Arctic seas, where by their myriads the water is discoloured for leagues. (Scoresby.) They are seen swimming on the surface in the heat of the day, as well as in the cool of the evening. Some of the larger kinds have prehensile tentacles, and their mouths are armed with lingual teeth, so that, fragile as they are, they probably feed on still smaller and feebler creatures (*e.g.*, *Endonostroma*). In high latitudes they are the principal food of the whale and of many sea-birds. Their shells are drifted on shore, and they abound in the fine sediment brought up by the dredge from great depths.

* Sir Wyville Thomson’s “Voyage of the Challenger,” Vol. I., p. 121.

Division a. THECOSOMATA.—Animals provided with an External Shell.

1. Family HYALIIDÆ:—Genera *Hyalia*; *Cleodora*; *Orescis*; *Cuvieria*; *Eurybia*; *Cymbalia*; *Tiedemannia*.
2. Family LIMACINIDÆ:—Genera *Limacina*; *Spiralis*; *Cheletropis*; *Macgillivrayia*.

Division b. GYMNOSOMATA.—Without a Shell.

3. Family CLIIDÆ:—Genera *Clio*; *Pseudonodomon*; *Pelagia*; *Cymodoce*.

Professor Sir Wyville Thomson, in his "Voyage of the *Challenger*," writes:—"When dredging off Portugal, at depths beyond five hundred fathoms, in the now well-known 'Globigerina Ooze,' that is to say, a greyish calcareous paste, soft on the surface, becoming firmer below, and made up in a great degree of the shells of foraminifera, chiefly of the genera *Globigerina* and *Orbulina*, entire or more or less broken up and disintegrated, along with the foraminiferous shells some other shells of much larger size enter, in varying proportions, into the composition of the ooze, or perhaps may be rather said to be mixed with it. These are principally shells of Pteropods, with a few of those of Heteropods and of pelagic Gasteropods. . . . "Most of these animals live on the bottom of the sea, as their organisation demands. One or two only of the shell-making genera are pelagic."

Of the genus *Clio* we "have in the Northern Polar Seas the *Clio borealis*, which is there found in such plenty as to constitute a considerable portion of the Greenland Whale's food. Passing over the intermediate oceans, that genus is, according to S. P. Woodward, represented in the Antarctic Ocean by some few species, but, according to H. and A. Adams, by only one, the *Clio australis*."



HYALIA LONGIROSTRIS.



HYALIA GIBBOSA.

"The Pteropoda are farther removed than the Heteropoda are from the typical Gasteropoda, and are much simpler in their structure. The head is not so markedly separated from the body, and the organs of sense are rudimentary. The body is conical and sometimes spiral, and is very usually contained in a delicate shell, sometimes spiral in form, more frequently conical or tubular, or like an ornamental flower-glass,

or like a watch-pocket. The foot is modified into two wing-like appendages, one on either side of the mouth. These are frequently brightly coloured when the animal is living, and different parts of the body show iridescent blues and greens. Multitudes of these little things may now and then be seen on the surface of the water, fluttering with their wings and glittering in the sunshine, to be compared with nothing more aptly than with a congregation of the more dressy of the Bombyx Moths, as one sometimes comes upon them on a sunny morning, just after a family of them have escaped from their chrysalises.

"The Pteropods are much smaller than the larger forms among the

Heteropods; the largest of the present day are not more than about an inch in length, though antediluvian species of the genus *Cuvularia* and its allies sometimes reach a length of nearly two

feet. They make up for their small size, however, by their numbers. Everywhere in the high seas they absolutely swarm. They are not always to be taken in the towing-net, as they seem to have a habit in the heat of the day, and when there is any wind, of

swimming a little way below the surface, but in a fine calm evening, no matter where, a haul of the towing-net can scarcely be made without catching many of them.

"The most widely distributed species in the Atlantic seems to be *Diacria trispinosa*, with a little pocket-like shell of some weight and strength, shaded purple and white. Several species of *Cuvularia* are



CLEODORA CUSPIDATA.



C. LANCEOLATA.



C. COMPRESSA.

abundant, the largest *C. tridentata*. *Clio cuspidata*, with a fretted shell, whose ornament reminds one of some of the fossil genera, is perhaps the species most frequently seen on the surface, and the one which shows the iridescent colouring with the greatest brilliancy. The several species of *Styliola*, much smaller than the others, are much more numerous, and sometimes throng the towing-net with their glassy needles. *Styliola subulata*, *S. acicula*, and *S. virgula* are in immense abundance, and very generally distributed. Some of these species sometimes reach the coast of Britain, but an indraught of northern water, which includes the British Islands in a fork, keeps out these oceanic things from our shores. If the British naturalist, to whom these things are usually unknown in a living state, will only push his towing-net work by a tug steamer, or his own or a friend's yacht, forty or fifty miles from the West Coast of Scotland or Ireland, he will get beyond the Arctic water, and will wonder, as I did, at the new animal world, in the shape of *Pteropoda*, *Heteropoda*, *Siphonophora*, and, above all, *Polycystina* and *Acanthometrina*, in all their wonderful varieties of form and sculpture, which will suddenly burst upon him.

"The *Pteropoda* extend far to the northward; one, *Limacina helicina*, with a delicate but very elegant spiral shell, and another, *Clione borealis*, which belongs to the shell-less subdivision, are frequently seen by Arctic voyagers in such numbers that they actually colour the surface of the sea in patches of many square miles in extent, and they are said to form a considerable item in the food of the Greenland Whale, which strains them out of the water as it passes through his mouth with his whalebone sieve. I have dwelt on this little group because their history is not very familiar, and because, small as they are, they play by no means an unimportant part in some of the recent geological processes of reconstruction."*

CHAPTER IV.

THE CONCHIFERA.

Class IV., CONCHIFERA—Bivalve Shells—Their Sedentary or Burrowing Habits—Structure of Bivalve Shells—Anatomy of Animal—Muscles, Mantle, Gills, &c.—Family 1. OSTREIDÆ—Oysters—Their Economic Value—Frank Buckland on the Oyster—The "Points" of an Oyster—Mode of Cultivation—The Young Oysters—Their Enemies—Their Sensitiveness to Cold—Ancient Shell Relics—2. AXOMIADÆ—3. PECTINIDÆ—Scallop Shells—The St. James's Shell—Vivacity of Young Pecten—The *Spondylus*, or Thorny Oyster—Value of Bivalve Shells—4. AVICULIDÆ—Pearl Oysters—Use of Shells—Value of Pearls—Pearl-fishery, Ceylon—The Divers—THE GREAT PINNA—5. MYTILIDÆ—Mussels—A Bridge Preserved by Mussels from Destruction—Boring Shells, Lithodomi—6. ARCADEÆ—7. TRIGONIDÆ—Trigonia—8. UNIONIDÆ—River Mussels—Pearl Mussels—9. CHAMIDÆ—10. TRIDACNIDÆ—Giant Clams—11. CARDIADÆ—12. LUCINIDÆ—13. CYCLADIDÆ—14. ASTARTIDÆ—15. CYPRINIDÆ—16. VENERIDÆ—17. MACTRIDÆ—18. TELLINIDÆ—19. SOLENIDÆ—"Razor-shells"—20. MYACIDÆ—21. ANATINIDÆ—22. GASTROCHELONIDÆ—Stone-borers—23. PHOLADIDÆ—Wood-borers—The Ship-worm.

CLASS IV.—CONCHIFERA.†

WE have already glanced at three of the great subdivisions of the Molluscan kingdom—namely, the Cuttle-fishes (Cephalopoda), the Snails (Gasteropoda), and the Pteropods. Let us now take a survey of a fourth group, the *Conchifera*, or "shell-bearing" Mollusca, better known as bivalves, from the fact that the majority are enclosed within a pair of shells united by a hinge, of which the Oyster, Mussel, Cockle, and Scallop are familiar examples. They are never found living on the land, as Snails and Slugs are able to do; and although, owing to their closely-fitting shells, the Dreissena, the Oyster and Mussel, and the fresh-water Cyclas are able to survive exposure for some time, yet as a whole the bivalves are all aquatic, and, with a few exceptions, are all inhabitants of the sea. They occur on the shores of every land in all climates, and are met with from low water-mark to a depth of many hundred fathoms.

* Sir Wyville Thomson's "Voyage of H.M.S. Challenger," Vol. I., p. 123.

† Latin, *concha*, a shell, and *fero*, I bear.

Most bivalves are sedentary in their habits, living in an erect position, either exposed or buried in the sea-bottom, resting on the edges of their shells, which are usually of equal size.

The burrowing forms have a stout muscular foot, with which they dig for themselves a cavity in the sand or mud, leaving only one end of their shell exposed to admit a current of water to the respiratory tube or opening, which also conveys to the animal within a constant supply of particles of food.

There is a tendency observable in bivalve shells, as well as in univalves, to grow in a spiral direction. This is especially well seen in *Isocardia*, whose separate valves resemble two spiral univalves—one right-handed, the other left-handed, with small spires and large apertures. In this shell, as in the common Cockle, one valve is placed on each side of the shell-fish, which is usually symmetrical, and lives in a vertical position as regards the plane of its valves.

To this there are exceptions: as, for example, the Oyster and Scallop, which (like Turbots and Soles among fishes) lie, the former on its left side and the latter on its right side, and fatten at their ease. The shells too are unequal, the deep valve in both cases being the lower shell, and the flat valve the upper.

The valves of the Cockle are united by an elastic ligament, and articulated by projecting teeth, which form a very complete hinge. It is obvious that the valve of a shell cannot grow so freely along the hinge as on the rest of the margin, but it may shoot out to great length, as in the "Razor shell" (*Solen*), or in three directions, as in the "Hammer-oyster" (*Malleus*), while in the "Heart-cockle" each valve takes a spiral. There are some fossil shells, called *Diceras*, in which the two valves resemble horns, and others called *Requienia*, with one valve produced into a horn. In *Chama* the umbones are also spiral.

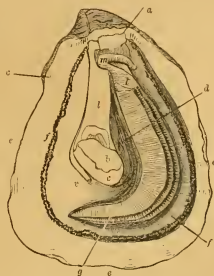
In many bivalves the beaks are turned forwards towards the head of the animal. But the Oyster is again an exception in this respect, and if among the exotic or fossil species you find some with spiral growth, the spiral is turned backwards; indeed, the number of exceptions is so great that one fears to make any general assertion. *Anomia*, when it grows inside shells, may have its umbo a little removed from the margin, and the fossil genera *Hippurites* exhibit every condition between a marginal ligament and a spiral beak, like *Chama*, and a patelliform valve, with a ligament wholly internal, and a central umbo.

The shell, considered as a defence, is most complete in those bivalves like the Oyster, which shut up close, and in those univalves which have an operculum, or door, to their houses.

Many bivalves gape a little at the sides (or ends), where the foot and the respiratory tubes are accustomed to be pushed out; whilst *Anomia* has a hole or notch in the right valve, through which a byssal plug passes, by which the animal is attached to foreign bodies.

Others bore into more or less hard substances, as wood, clay, chalk, coral, limestone, and sandstone, and many of these boring Mollusca become so remarkably changed and modified in appearance, owing to the life they lead, that, like *Magilus*, already described, we can hardly recognise them as bivalve shells at all.

If we examine the inside of the empty valve of an Oyster, a Pecten, or a Spondylus shell we shall readily detect a single circular scar a little to one side of the valve. This is the point of attachment for the great shell-muscle. If we look at the valve of a *Cytherea*, or any

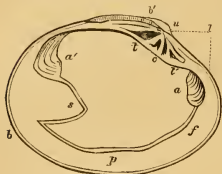


ANATOMY OF A COMMON OYSTER.*

* *a*, *e*, the edge of the valve along which (when living) the mantle is attached to the shell; *b* and *c*, adductor muscle; *b*, a portion which separates easily from the shell, *c*, part firmly attached, and which has been cut through; *d*, a convex broad arc on mantle, indicating the part where the gills are attached to it, and forming the outer wall of the dorsal water-chamber into which the gills open; *e*, the true outline of the mantle, the mantle being represented in its shrunk condition, as seen upon opening the oyster; *f*, silvery muscular lines on the mantle, much branched; *f*, fringed edge—the edge of the mantle is split in its own planes about $\frac{1}{3}$ of an inch, and the space between the two edges is fringed with several rows of minute short tentacles, between which is a dusky pigment; *g*, the gills, or branchiae; *h*, the liver; *i*, the labial tentacles; *j*, the mouth; *a*, the hinge-line; *k*, the vent.

other shell of that group, we shall observe two of these scars, one on either side (*u* *u*). This has led to the former being called *Monomyaria* * (having only one shell-muscle); the others *Dinyaria*† (having two shell-muscles).

These muscles are also called adductors, their functions being to close the valves of the



ANATOMY OF CYTHEREA.

u, is theumbo of the valve; *u'*, the hinge cartilage; *t*, the "tamille"; *b*, the posterior of the border of the valve; *f*, the front or anterior border; *a, a'*, the scars where the two great adductor muscles of the animal are attached; *t, t'*, indicate the hinge-teeth.

shell and hold them tightly together. We may also notice in the valve of the Monomyarian a simple unbroken line (*p*) just within the margin of the shell. This is the line of attachment of the animal's mantle to its shell, and is called the pallial‡ border, because the mantle is the membrane which envelops all the Mollusca, and is that structure which secretes the shell. This line is simple in the Oyster and its allies, which have no siphonal tubes; and indented in shells like *Cytherea* (*s*), which are provided with siphons which could be drawn within the valves of the shell by muscles specially provided for that duty. The soft parts of an ordinary bivalve shell (see figure given on page 249) are very simple, consisting of the branchiæ, or gills (*g g*), the mantle (*m*); the incurrent and excurrent siphons (whose position is marked in the figure by two arrows);

the foot (*f*), which enables many of the bivalves to burrow, and which in some species secretes the threads of the byssus, by which they can moor themselves to rocks or floating objects. Then there are the shell-muscles, and the muscles of the foot and of the siphons, and the muscular fibres of the mantle, the stomach, liver, heart, and intestine. The water passing in by the incurrent siphon or tube is conveyed to the gills, through the folds of which it passes, the particles of food, whether living or dead, being guided by the labial tentacles, or lip-feeders, to the mouth, the excurrent orifice serving, as in the Tunicata, to carry away what is done with.

Division a. ASIPHONIDA.§—In this section the lobes of the mantle are free, or only united at the point which separates the branchial chamber from the excurrent chamber. The animal has no respiratory siphons.

FAMILY I.—OSTREIDÆ.

The animals of this family are marine; the mantle is free, only slightly adhering to the edges of the shell. The shell is closed by a single muscle; valves unequal, adhering by one valve.

Genus *Ostrea*. The shell of the Oyster is irregular; the upper valve flat, the lower convex, often plaited or lamellated; pearly within; ligament triangular; margin of mantle finely fringed; gills almost equal, united behind to one another and to the mantle, and completely enclosing the branchial sac. There is an intimate connection between the mantle of the mollusc and its shell. The Oyster, as we see it on the supper-table, is much smaller than its shell, and adheres only by its glistening shell-muscle; but when alive, its mantle extends to the very edge of the valves, lining the whole interior, and having a slight adhesion, especially at the edge of the valves, which is speedily ruptured, however, when the poor animal is forcibly invaded by the fishmonger's knife. Oysters are found in the temperate and tropical seas all over the world. Nearly 100 species have been described.

No shell-fish has, probably, endured more severe havoc from mankind than the common Oyster, for it is only in comparatively late years that it received the protection of Mr. Frank Buckland, and became a subject for Parliamentary Committees to discuss and Government to legislate for.

The shores of Denmark and her islands are marked by vast shell-mounds (køkken-møddings), indicating the primitive taste for *Ostrea edulis*. No doubt vast strata of oyster-shells must exist beneath London, when we consider that from 20,000 to 30,000 bushels of "Natives," and 100,000 bushels of "Sea Oysters" were (thirty years ago) annually supplied to the London market. And although, owing to the increased price of this mollusc, a considerable falling off has occurred of late in the supply of "Natives," Oysters have been imported in large quantities into England from Holland and the United States.

"Sea Oysters" (i.e., Oysters naturally grown) obtain their majority in four years, but "Natives"

* Greek, *monos*, one; and *mus*, a muscle.

† *dis*, two; and *mus*.

‡ From Latin, *pallium*, a cloak or mantle.

§ Greek, *a*, without; *siphon*, a tube.

(i.e., Oysters artificially cultivated) do not reach their full growth in less than five or seven years. It was the bringing of immature Oysters to market which, to a great extent, produced the subsequent scarcity of this article of food. Many other species of Oysters are eaten in India, China, Australia, &c.

Frank Buckland * writes :—"There are almost as many kinds of Oysters as there are kinds of dogs ; no two Oysters are exactly alike, but those which come from the same locality bear a general resemblance to each other, so that any one accustomed to handle and criticise Oysters can tell pretty well where they were reared. Taking the English coast round, there are not many localities suitable for Oyster-farming. The reason of this is that where sand is Oysters cannot possibly exist ; the grains of sand get into the hinge of the Oyster, and, like a stone in the hinge of a door, they prevent the opening and shutting of the valves of its shell. The sand then smothers the Oyster, his valves gape, and he dies. For this reason there are no Oysters in the great estuary of the Solway, or in Morecambe Bay (the head-quarters for Cockles), the estuary of the Flintshire Dee, the vast expanse of Cardigan Bay, and the greater part of the estuary of the Severn. Several times has the idea been started to use for an Oyster-farm the great plain of the Maplin Sands at the mouth of the Thames, but Oysters cannot possibly thrive there ; it is all sand. From the Land's End to the North Foreland we begin to find Oysters in the various estuaries and land-locked bays : for example, Falmouth, Plymouth, Poole Harbour, the Solent, Portsmouth, Hayling, Havant, &c. ; also in the Isle of Wight, in the Medina River, Brading, &c. On the north-east coast there are but few Oysters, Boston Deepes and Holy Island being excepted.

"Oysters may be divided into natives and deep-sea, and between these there are several varieties. The deep-sea Oysters are as different in form and fashion from the natives as a Clydesdale cart-horse is from a thoroughbred race-horse. Like horses, Oysters have their points. The points of an Oyster are—first, the shape, which to be perfect should resemble very much the petal of a rose-leaf. Next, the thickness of the shell ; a first-class thoroughbred native should have a shell of the tenuity of a thin china or a Japanese tea-cup. It should also have an almost metallic ring, and a peculiar opalescent lustre on the inner side ; the hollow for the animal of the Oyster should be as much like an egg-cup as possible. Lastly, the flesh itself should be white and firm, and nut-like in taste. It is by taking the average proportion of meat to shell that Oysters must be critically judged. The Oysters at the head of the list are, of course, 'natives,' the proportion of a well-fed native is one-fourth meat. The nearest approach to natives both in beauty and fatness are the Oysters from Milford, in South Wales. The deep-sea Oysters, such as the white-faced things dredged up in the Channel between England and France, and stored at Shoreham, near Brighton, are one-tenth meat ; while the very worst are some Frenchmen, which are as thin and meagre as French pigs. I have weighed half-a-dozen natives ; the meat contained in these weighed two ounces ; the value, therefore, of Oyster meat—at 3s. 6d. per dozen—is fourteen shillings per pound, just the cost of a 14 lb. leg of mutton.

"It is not to be supposed for a minute that the high-classed aristocratic native has reached the position of the King of Oysters without a great deal of human labour and intelligence having been spent during many generations of dredgermen upon his education. The mouth of the Thames, within a line drawn from about Walton on the north to Margate on the south, may be considered as the home of the true British native. This kind of Oyster seems to thrive only upon London clay. So far as my experience goes, I have come to the conclusion that a fatting place for Oysters is seldom also a breeding place ; the fatting grounds must always be situated in water, with which a certain amount of river water is mixed with sea water. Whitstable is *par excellence* the best fatting ground in the world, because the food of the Oyster (a subject which has hitherto not been sufficiently investigated) is there present in the greatest abundance, and also because at Whitstable the Oysters are continually being worked by the dredge. The food of the Oyster consists of very minute organisms (such as Infusoria, Rhizopoda, and microscopic larval forms of Cœlenterata).

* In many a far-off village upon the English coast, and on many a Salmon-stream in Scotland, the name of this amiable and accomplished naturalist will long be cherished as a household word. Few men had more friends. Enemies he had none, save those "rascals," as he styled them, "who wouldn't let a poor Salmon have a chance to come up stream to spawn." He was the true friend of animals of all kinds, and all animals loved Frank Buckland.

"The Oyster's mouth is situated between the delicate folds of what is ordinarily called the beard, *i.e.*, the breathing organs, and by following down the course of the gullet the stomach can easily be found, embedded in the thick part of the body of the Oyster, which is really the liver. It is in the month of June that Oysters mostly spawn; the 'spat,' as it is called, resembles very fine slate-pencil dust, and the number of spats in one Oyster I find from experiment varies from 829,000 to 276,000 individuals. One fine hot day the mother Oyster opens her shell, and the young ones escape from it in a cloud, which may be compared to a puff of steam from a railway engine on a still morning. Each

YOUNG OYSTERS FURNISHED WITH LOCOMOTIVE ORGANS.

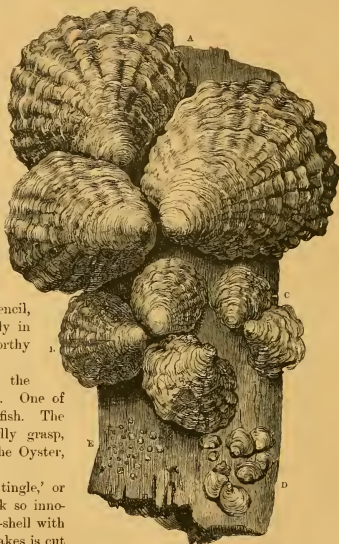
little Oyster is provided at its birth with swimming organs, composed of delicate cilia, and by means of these the little rascal begins to play about the moment he leaves his mother's shell. Unless born in an enclosed water paddock, he swims away with the tide to and fro until he dies, or finds a rest suitable for him. Oysters, in fact, may be said to 'swarm' like bees, and many a bed has been discovered the origin of which is attributable to a swarm of Oysters having alighted on the spot.

"The little Oysters, the size of a fourpenny-piece to a sixpence, are called 'brood,' the larger are called 'half ware,' and these are sold by what is called a 'wash,' which contains twenty-one quarts and a pint. These young Oysters increase in size by adding to the margin of their shell a very delicate layer of a horn-like elastic substance, at first almost as thin as gold-beater's skin, but which eventually hardens into shell: this is called the 'growth.' In a well-marked native the rings of annual growth are plainly perceptible. If the shell be well washed the growth will take the markings of a pencil, and it will be found that the Oyster is generally in his fifth or sixth year before he is thought worthy of an introduction to London society.

"Being of a very delicate tender nature, the Oyster has a great many difficulties to encounter. One of his worst enemies is the 'five finger,' or Star-fish. The 'five finger' entwines the Oyster in his deadly grasp, and by protruding his elastic stomach eats up the Oyster, leaving the empty shells, known as 'clocks.'

"The next worst enemy is the 'Whelk tingle,' or 'Dog Whelk.' These rascals, although they look so innocent, have the power of boring into the Oyster-shell with their rasp-like tongue. The hole this creature makes is cut very clean, as if bored by a jeweller's diamond, and they often destroy hundreds of pounds' worth of property. He who would invent a trap to catch these 'Dog Whelks' would indeed be a benefactor to Oyster fishery proprietors.

"The Oyster is most intolerant of cold and very tolerant of heat. There are no Oysters in the Arctic seas; in all tropical seas they abound, but are not always edible. In the winter season owners of Oyster layings watch the weather most carefully, shifting Oysters from the fore-shore into deep



GROUP OF OYSTERS OF DIFFERENT AGES ATTACHED TO A BLOCK OF WOOD.

A, Oyster of Twelve to Fifteen Months; B, of Five to Six Months; C, of Three to Four Months; D, of One to Two Months; E, Twenty Days after Birth.

water, for if the frost catches them it nips them up. Particularly dangerous are also the floods from melted snow, and as fresh river water alone is sufficient to kill Oysters, much more so are they in danger if the temperature is reduced by melting ice or snow. Valuable layings of Oysters have thus been frequently destroyed by winter floods too powerful for the flowing tide to dilute. This great abhorrence of cold on the part of high-bred Oysters, such as natives, is, in my opinion, one of the principal causes of their high price. Of late years the summers have been very cold, and although the water may perchance have attained to a certain amount of heat, yet the cold nights knock all the warmth out of it again. Above all, it is necessary for a fall of spat that the temperature should not jump up and down, but be as equable as possible. The young Oysters cannot help being born, and when born they must take their chance of the weather. If it is cold, they die; if it is warm, and they are lucky enough to find cradles in the form of 'culch' suited for them, they hold on as tight as barnacles, and have a chance of living."

Many British cists and cairns have disclosed relics in the form of shell necklaces and bracelets made of the Oyster, Limpet, and Cockle-shells, the contents of which supplied an important source of food. For not only in the ancient kitchen middens of Northern Europe, but mingling with more ancient cave deposits, as in Kent's Cavern, lay heaps of the shells of such edible Molluscs, the refuse of the repasts of the old cave-men, which show one resource on which they depended for subsistence. America, too, had its ancient shell and refuse heaps, as at Cannon's Point, St. Simon's Island, Georgia, where vast mounds of Oyster and Mussel shells, intermingled here and there with a *Modiola* or *Helic*, and with flint arrow-heads, stone axes, and fragments of pottery, cover an area of not less than ten acres. They also abound upon all the sea islands of the Southern States, and in many cases constitute regular sepulchral mounds or shell cairns. One of these singular cairns on Halling's Island, in the Savannah River, more than two hundred miles from its mouth, is an elliptical mound, measuring nearly three hundred feet in length, and enclosing human skeletons, &c. On the islands, and along the coasts of Georgia and Florida, the inexhaustible supplies of Oysters, Conches, and Clams furnish abundant food. Around all the Indian villages these shell may be observed accumulated in vast heaps; and even now at places they show the circular hollow where the native hut once stood.

FAMILY II.—ANOMIADÆ.

Genus *Anomia*.* The shells of *Anomia* are very variable in form, being nearly always attached to the surface of shells of other Mollusca, the pattern of whose markings they mould themselves to. The shell is translucent, nearly round, and attached by a plug passing through a hole or notch in the right valve; the lower valve is concave, the upper valve convex, and the muscular impression single. Twenty species are found living. They are not edible. They occur from low water to 100 fathoms.

Genus *Placuna*,† "Window-shell." The valves of *Placuna* are nearly round and almost flat; the hinge cartilage is fixed by two ridges on the right valve, with corresponding grooves on the left; the muscular impression is double; there are one large round scar, and a smaller, crescent-shaped, in front; the shell is pearly and translucent. Four species are living in India, Australia, China, and Ceylon.

"The Tamblegam Lake produces in singular perfection the thin transparent Oyster (*Placuna placenta*), whose clear white shells are used in China and elsewhere as a substitute for window-glass. They are also collected annually for the sake of the diminutive pearls contained in them. These are exported to the coast of India, to be calcined for lime, which the luxurious affect to chew with their betel. These pearls are also burned in the mouths of the dead. So prolific are the Mollusca of the *Placuna*, that the quantity of shells taken by the licensed renter in the three years prior to 1858 could not have been less than eighteen millions. They delight in brackish water; and on more than one occasion an excess of either salt water or fresh has proved fatal to great numbers of them."‡

The pearl fishery of Lake Tamblegam, near Trincomalee, clears £300 a year; individual pearls of *P. placenta* do not exceed 6s. in value.

* Greek, *anomis*, unequal.

† Greek, *plakous*, a thin cake.

‡ Sir J. Emerson Tennent: "Ceylon," vol. ii., p. 492.

FAMILY III.—PECTINIDÆ.

Genus *Pecten*.* The shell of the "Scallop" is fan-shaped, or nearly circular, and has the following characters—the right valve deep, the left valve flat, usually ornamented with radiating ribs; hinge-line eared; valves united by a narrow ligament; hinge cartilage internal; the mantle quite open, its border double, and finely fringed with a row of round black eyes at its edge. The Scallop ranges from three to forty fathoms. Its body is bright orange or scarlet. The shell is used for "scalloping Oysters." The Pectens are characterised by the brilliant red and yellow colouring of their shells, few groups exceeding them in elegance of form and ornamentation.

Pecten maximus, commonly known as "Scallops" in the London market, "Queens" at Brighton, and "Frills" on the coasts of Dorset and Devonshire, are now almost as much eaten as Oysters; but they require to be cooked first.

An allied species has received the name of "St. James's shell" (*Pecten jacobæus*). It was worn by pilgrims to the Holy Land. The fossil Pectens found in the sub-Apennine formation of Italy were supposed by early writers to have been dropped by these devout persons on the road. Parnell says of the hermit:—

"He quits his cell; the pilgrim staff he bore,
And fixed the *scallop* in his hat before."

The aged Pectens certainly are sedentary in their habits, as is testified by the mass of *Bryozoa*, *Serpule*, *Acyonium*, and *Balani* attached to their upper flat valve. They do not, however, fix themselves, like the Oysters, by the deep valve, but some species are moored by a byssus to stones or the stems of the *Laminarie*.

The young Pectens swim freely by rapidly closing and opening their valves. The writer, when dredging with Mr. MacAndrew, off Coruña, has seen *Pecten opercularis*, two inches in diameter, swim rapidly out of the dredge as it was being hauled up alongside the boat.

Genus *Lima*.† In this genus the valves are equal and obliquely oval; the front side is straight and gaping, the posterior is rounded and closed; the umbones of the valves are separated; the hinge-line is eared; the valves are smooth or radiately ribbed; the muscular impression is large, lateral double; the shell always white.

"The *Limas* are either free or spin a byssus; some make an artificial burrow when adult, by spinning together sand or coral fragments and shells; but the habit is not constant." (Forbes.) "*L. hians* is pale or deep crimson, with an orange mantle. When taken out of its nests it is one of the most beautiful marine animals to look upon. It swims with great vigour, like the Scallop, by opening and closing its valves, so that it is impelled onwards and upwards in a succession of jumps." (Landsborough.)

Twenty species are found living at a depth from one to one hundred and fifty fathoms in Norway, Britain, India, and Australia.

Genus *Spondylus*. The Thorny Oyster has an irregular shell, with divergent ribs, terminating in foliaceous spines. It is found attached to foreign bodies by the right valve. The umbones of the shell are wide apart and eared, the lower valve has a triangular area to the hinge, and two curved teeth in each valve; the animal is like that of *Pecten*. The Spondyli inhabit coral-reefs, being attached to the branches of the growing coral. Seventy species are known living in the tropics.

A structure analogous to the chambered shell of the Cephalopod occurs in the Thorny Oyster, or *Spondylus*. In aged specimens the shell, instead of increasing in size, becomes thicker in its interior by the addition of inner layers of shell, which are distinct from the outer and from each other. The cavities thus formed are found to contain water, which, however, evaporates after the specimens have been placed in a dry situation for a long period; but the water is again absorbed by immersing the specimens for a sufficient number of hours. This reduction of the inner space appears to be effected in order to counteract the continued increment of the shell (by deposits of new shell-matter along its margin from the border of the mantle) at a greater rate than is required for the accommodation of the soft parts of the animal.

The tubes of *Vermetus* and *Magilus*, and the apices of *Triton*, *Turritella*, and *Euomphalus* become either partitioned off or filled up solid in the continued growth of the animal.

* Latin, *pecten*, a comb.

† Latin, *lima*, a file.

Few of the bivalves have been esteemed "fancy" shells or commanded high prices, but some of the *Chamas* and *Spondyli* are very beautiful, and might well distract a Dutch or French collector. Sowerby valued *Spondylus regius*, in the Tankerville collection, at £25, the best *Chama* at £3 3s., and *Isocardia* at £8 8s. (?) ; *Etheria elliptica* at £21 (?) ; and the *Lucina childreni*, now in the British Museum, at £10 10s., because it had the hinge reversed. Mr. Norris gave £20 for a *Mülleria*, an extraordinary shell to the conchologist (although most unattractive to the eye), of which M. D'Orbigny sent several specimens to the British Museum in exchange for a fossil *Pentacrinus*.

The genus *Plicatula* has an irregular shell, with plicated valves, and is fixed to some foreign body by the beak of the right valve. The *Plicatulae* are tropical shells. Ten species occur in the East and West Indies, the Philippines, &c.

FAMILY IV.—AVICULIDÆ.

The shell is very oblique and the valves unequal ; it is attached by a byssus ; they are pearly within, the outer layer is cellular, the lobes of the mantle are fringed at the margin ; it has two gills on each side. The Pearl Oysters, or "Wing-shells," as they are called, are mostly tropical.

Genus *Avicula*. The shell is very unequal ; there is a fold for the byssus in the right valve, beneath the ear of the shell ; there are one or two small teeth in the hinge ; the valves are obliquely oval. Twenty-five species occur living in about twenty-five fathoms water in Britain, the Mediterranean, India, &c.

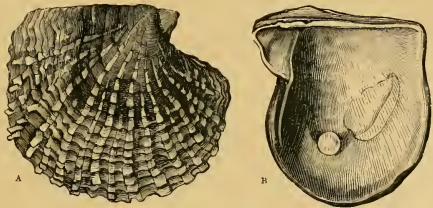
Genus *Meleagrina*. The valves of the Pearl Oyster are flattish and nearly equal in size, the gills are equal and crescent-shaped, the foot finger-like and grooved. *Meleagrina* is less oblique than the other *Aviculidæ*. They are found living in Madagascar, Ceylon, Swan River, &c.

The shells of the "Pearl Oyster" afford the substance known as "mother-o'-pearl," so largely employed in the manufacture of buttons and for *papier-mâché* inlaid-work, &c.

Prof. T. C. Archer mentions that there are three principal kinds of these mother-o'-pearl shells brought to market at Manila (which was the *dépôt* for the Pearl Oyster trade).

One kind is known as the silver-lipped Pearl Oyster, from the Society Islands ; another the black-lipped variety, from Manila ; the third, from Panama, is smaller than the others. About 250 tons of these shells were annually imported into Liverpool alone. They also yield the "oriental" pearls of commerce. The principal pearl fisheries are in the Persian Gulf and Ceylon. Pearls are produced by many bivalves, but by none in greater perfection than by the *Meleagrina margaritifera*. They are caused by particles of sand or other foreign substance finding its way into the cavity of the valves, and getting between the animal and its shell ; the irritation causes a deposit of nacre, forming a projection on the interior, generally more brilliant than the rest of the shell. Completely spherical pearls can only be found loose in the muscles or other soft parts of the animal. The Chinese obtain them artificially by introducing into the living *Hyria* foreign substances, such as pieces of mother-o'-pearl fixed to wires, which thus become coated with a more brilliant material. Similar prominences and concretions—pearls which are not pearly—are formed inside porcellaneous shells. These are as variable in colour as the surface on which they are formed. They are pink in *Turbinella* and *Strombus* ; white in *Ostrea* ; white or glossy, purple or black, in *Mytilus* ; rose-coloured and translucent in *Pinna*.

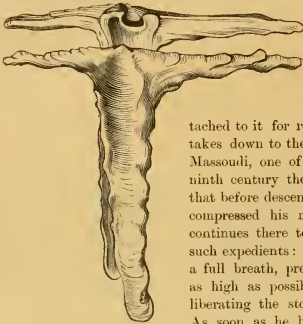
The pearl fisheries of the Persian Gulf and Ceylon give employment annually to several hundred boats and many thousand men. The entire amount of revenue derived from the pearl fisheries of



MELEAGRINA MARGARITIFERA—A, OUTSIDE ; B, INSIDE OF SHELL.

Ceylon in nine years (from 1828 to 1837), according to Mr. James Steuart, the Inspector of Pearl Banks, was £227,131, but it has since decreased very considerably. Mr. Hope possessed a pearl measuring two inches in length and four in circumference, and weighing 1,800 grains. This is said to be the largest pearl known. A very fine pearl *bouton* was sold in London in 1860 for £2,000: it measured about five-eighths of an inch. Good pearls of two grains weight are common, and fetch about 7s. 6d. each; pearls weighing five grains are worth £2 each; pearls of ten grains' weight sell for £7 and £8 apiece. But the best market for pearls is in India itself, where they are more highly esteemed than in Europe, and realise far higher values.

Sir Emerson Tennent gives the following interesting account of diving for Pearl Oysters on the coast of Ceylon:—"On my arrival at Arippe, the pearl-divers, under the orders of their Adapanaar, put to sea, and commenced the examination of the banks. The persons engaged in this calling are



HAMMER OYSTER
(*Mallens alba*).

chiefly Tamils and Moors, who are trained for the service by diving for chanks. The pieces of apparatus employed to assist the diver in his operations are exceedingly simple in their character: they consist merely of a stone, about thirty pounds' weight (to accelerate the rapidity of his descent), which is suspended over the side of the boat, with a loop attached to it for receiving the foot; and of a network basket, which he takes down to the bottom and fills with the Oysters as he collects them. Massoudi, one of the earliest Arabian geographers, describing in the ninth century the habits of the pearl-divers in the Persian Gulf, says that before descending each filled his ears with cotton steeped in oil, and compressed his nostrils by a piece of tortoiseshell. This practice continues there to the present day; but the diver of Ceylon rejects all such expedients: he inserts his foot in the 'sinking stone' and inhales a full breath, presses his nostrils with his left hand, raises his body as high as possible above water, to give force to his descent, and, liberating the stone from its fastenings, he sinks below the surface. As soon as he has reached the bottom the stone is drawn up, and the diver, throwing himself on his face, commences with alacrity to fill his basket with Oysters. This, on a concerted signal, is hauled

up rapidly to the surface, the diver assisting his own ascent by springing on the rope as it rises." "Improbable tales have been told of the capacity which these men acquire of remaining for prolonged periods under water. The divers who attended on this occasion were among the most expert on the coast, yet not one of them was able to complete a full minute below. Captain Steuart, who for many years filled the office of Inspector of the Pearl Banks, assured me that he had never known a diver to continue at the bottom longer than eighty-seven seconds, nor to attain a greater depth than thirteen fathoms; and on ordinary occasions they seldom exceeded fifty-five seconds in nine fathoms' water.

"The only precaution to which the Ceylon diver devotedly resorts is the mystic ceremony of the shark-charmer, whose exorcism is an indispensable preliminary to every fishery. His power is believed to be hereditary; nor is it supposed that the value of his incantations is at all dependent upon the religion of the operator, for the present head of the family happens to be a Roman Catholic. At the time of our visit this mysterious functionary was ill and unable to attend; but he sent an accredited substitute, who assured me that although he himself was ignorant of the grand and mystic secret, the fact of his presence as a representative of the higher authority would be recognised and respected by the Sharks." ("Ceylon," Vol. II., p. 563.)

Genus *Perna*. These shells, like the *Avicula*, vary greatly in form, some being very oblique and inequivalved, others nearly equivalved; they have a row of about nine cartilage pits near the hinge, and are attached by a byssus. Eighteen species are found in tropical seas.

Genus *Pinna*. Shell acutely triangular, thin, translucent, and brittle, equivalved; hinge toothless, mantle of animal doubly fringed, foot elongated and grooved. *Pinna* spins itself a powerful byssus, by

which it is attached. The great *Pinna* excels any other in the quantity and fineness of its silk byssus, which has been woven into articles of dress. In early times these were so highly prized as to be worn only by emperors and kings. At Taranto, in Italy, it is still mixed with about one-third of real silk, and made into gloves, caps, stockings, &c., of a beautiful brownish colour. These are valued as objects of curiosity, but too expensive for general use, the price of a pair of gloves on the spot being about six shillings, and that of a pair of stockings eleven.

A specimen of this manufactured molluscan silk, as well as the raw material, may be seen in the Shell Gallery of the British Museum, beside the valves of the great *Pinna*. This is one of the largest bivalves, attaining a length of two feet. It lives from low water to sixty fathoms.

FAMILY V.—MYTILIDÆ.

The shell of the Mussel is oval and equivalved, the edges closely fitting, the ligament internal, hinge toothless; they are mostly marine and attached by a byssus. Some of the members of this family exhibit a propensity for concealment, frequently spinning a nest of sand and shell-fragments, burrowing in soft substances, or secreting themselves in the burrows of other shells. Others are gregarious, living in vast beds of tens of thousands clustered together, adhering by their thread-like byssus.

Genus *Mytilus*. The "Sea Mussel" has a wedge-shaped shell, with the umbones at the end; it moors itself to piles and stones by a strong and coarse byssus. *Mytilus edulis*, the common edible Sea Mussel, although far less highly esteemed than the Scallop or Oyster, is nevertheless much in request as an article of food. It is difficult to ascertain the consumption of Mussels in London, but in Edinburgh and Leith it is estimated at 400 bushels annually. Dr. Knapp states that from thirty to forty millions are collected yearly in the Firth of Forth alone, and used as bait for the deep-sea fishery. They form no small item of consumption in the north of Ireland, boats full being constantly sent to Belfast Market.

If any one should reflect upon the *Mollusca* as undeserving so much notice, and mention the *Teredo* as an instance of a destructive member of the class, let him read of the utility of another, the common Mussel, in maintaining the long bridge of twenty-four arches across the Torridge River, near its junction with the Taw, at the town of Bideford, in Devonshire. At this bridge the tide runs so rapidly that it cannot be kept in repair with mortar. The Corporation, therefore, keep boats employed in bringing Mussels to it, and the interstices of the bridge are kept filled with Mussels. It is supported from being driven away by the tide entirely by the strong threads of the byssus which these Mussels fix to the stonework.

"*Mytilus edulis* is no friend to the Oyster. A colony of Mussels will, unknown to the proprietor of the Oyster bed, often settle upon the *spem gregis* of 'half ware,' so carefully deposited to grow fat. The Mussels, immediately on settling down, spin

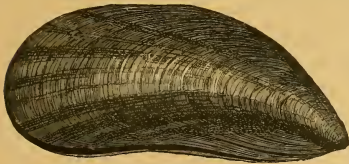
their curious silk-like webs, as seen under piers, &c., by means of which they are enabled to anchor themselves so firmly. The run of the tide then brings mud, the webs of the Mussels collect it, and the Oysters underneath, unless released by the dredge, are smothered like the little princes in the Tower." (Frank Buckland.)

Mussels are found living in all seas. About seventy species have been described.

Genus *Modiola*, the "Horse Mussel," is distinguished from the edible Mussel by its habit of burrowing; they are met with from low water to 100 fathoms. The shell is oblong and inflated, but



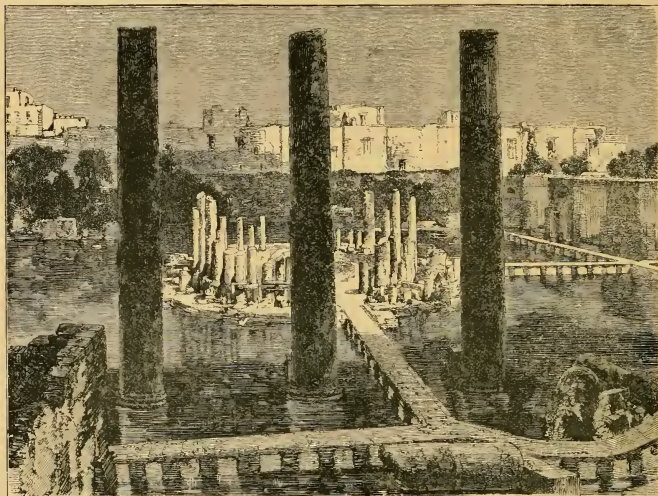
PINNA NOBILIS, WITH ITS BYSSUS.



SEA MUSSEL.

the umbones are not at the extreme termination of the shell, as in *Mytilus*. Seventy species are found in tropical seas.

Lithodomus, the Date-shell, bores into corals and even hard limestone rocks. The animal, which is like the common Mussel, is eaten in the Mediterranean. Perforations made by *Lithodomi* in limestone cliffs and in the columns of the Temple of Serapis, at Puteoli, have afforded conclusive evidence of changes in the level of the sea-coasts in modern times. (Lyell.)



THREE ERECT COLUMNS OF THE TEMPLE OF SERAPIS AT PUTEOLI BORED BY LITHODOMI.

Genus *Dreissena*. The animal bears a triangular fan-shaped shell; the mantle is closed throughout, except for the passage of the foot, and of two tubular orifices for the purposes of excretion and respiration. The right valve has a slight byssal sinus. "*Dreissena polymorpha* is a native of the Aralo-Caspian rivers. In 1824 it was observed by Mr. J. Sowerby in the Surrey Docks, to which it appears to have been brought with foreign timber in the holds of vessels. It has since spread into the canals, docks, and rivers of many parts of England, France, and Belgium, and has been noticed in the iron water pipes of London." (S. P. Woodward.)

FAMILY VI.—ARCADE.

The shell is covered with a strong epidermis hinge line, often elongated and toothed; the valves are tumid and equal. The foot of the animal is large, curved, and deeply grooved.

Genus *Arca*. The "Arks" have thick, inflated, ribbed, and striated shells; the umbones anterior are divided by a lozenge-shaped hinge area; the foot is long and pointed, the mantle bears ocelli on its border. One division of the Arcs (*Byssarca*) has a wide byssal aperture, filled with a horny cone; these conceal themselves under stones at low water, in crevices of rocks, and the empty burrows of boring molluscs. They inhabit all the warm seas of the globe, from low water to more than 200 fathoms. One species lives in the Ganges, 1,000 miles from the sea. (Benson.)

Cucullea resembles *Byssoarca*, but the valves are squarish and striated, and fit close together. Two species are found living in Nicobar, China, &c.

The characters of the genus *Pectunculus* are—shell nearly circular, valves equal, striated radially, hinge thick, with a row of teeth, and a ligament area between the beaks of the valves. The animal has a large foot, and the mantle is open and provided with ocelli. Fifty-eight species are found living in the West Indies, Britain, New Zealand, &c.

Genus *Limopsis* is like a small oblique *Pectunculus*, with a triangular cartilage pit in the centre of its hinge. Four species are known living in the Red Sea, Japan, Britain, &c.

Genus *Nucula*. In this genus the valves are somewhat triangular, with their beaks turned backward; interior of valves pearly, hinge with a large cartilage pit, and numerous sharp teeth on each side. The *Nuculae* are burrowers, and have very wide distribution, from Norway to Japan, living from five to more than 100 fathoms in depth. Seventy living species are known.

Genus *Leda* resembles *Nucula*, but the shell is more elongated and pointed behind. It is found in the Northern and Arctic seas, living from ten to 200 fathoms.

Genus *Solenella*. In this genus the shell is nearly oval; the valves are pearly within; the hinge ligament is external; the line of the mantle has a large and deep fold; the siphonal tubes are joined together; they are long and slender, and can be drawn completely into the shell. They are found living at Valparaiso, New Zealand, &c.

Genus *Solemya*. The valves of the shell are somewhat cylindrical and elongated, and gape at each end. They are covered with a dark horny epidermis, which overlaps the margins. There are no hinge teeth. Four species only are known in America, Africa, and the Canaries.

FAMILY VII.—TRIGONIADÆ.

The shells of this family have the valves equal, triangular in form, closely fitting, with the umbones of the valves turned backwards. The hinge teeth are diverging, the border of the mantle is simple, the interior of the shells pearly; the hinge ligament is external. The foot is long and curved; there are two gills on each side, and the mantle is open.

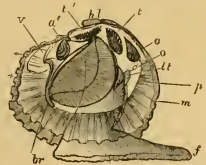
In the genus *Trigonia* the shell is thick and ornamented with tubercles, or with ribs arranged in concentric or radiating lines; the posterior side of the valves is angular; the shells are almost entirely composed of pearl. Like the young *Pectens*, the *Trigoniae* are very active bivalves. A *Trigonia*, taken alive from the dredge by Mr. S. Stutchbury, and placed on the gunwale of the boat, leapt overboard, clearing a ledge of four inches. They are probably migratory, as in dredging for them it is very uncertain where they may be obtained, though they abound in some parts of Sydney Harbour. *Trigonia* is almost an extinct form, three species or varieties only being known living in Australia, whilst more than one hundred are found fossil, widely distributed over the globe.

FAMILY VIII.—UNIONIDÆ.

The animal bears a pearly shell, with the mantle lobes freely open except behind, where they are united to form the branchial and excretory siphonal orifices, which are simply pouted. The foot is large and free.

* Explanation of the lettering in this figure:—*a*, anterior adductor muscle; *d*, posterior adductor muscle; *h l*, hinge ligament; *t t'*, pits for the reception of teeth in the right valve; *f*, foot; *v*, excreting orifice; *m*, free margin of the mantle; *o*, the mouth; *p*, line (corresponding with the pallial impression in the shell) from which the muscular fibres of the mantle originate. The central portion of the mantle is thin and transparent. Through it are seen—*br*, the right branchial leaves; and *l t*, the labial tentacles of the right side of the mouth. The arrows indicate the points at which the respiratory currents enter and escape.

† *f f*, hinge-teeth and sockets; *a' a*, adductor muscles.



ANATOMY OF TRIGONIA PECTINATA.*



TRIGONIA COSTATA.



TRIGONIA PECTINATA.†

Genus *Unio*,* the "River Mussel." The shell is rather stout; the hinge is composed of interlocking erect teeth on the anterior side, and elongated marginal teeth, which are sometimes obsolete, on the posterior.

The Pearl-bearing Mussel (*Unio margaritifera*) afforded the once famous British pearls. It is found in the mountain streams of Britain, Lapland, and Canada, and is used for bait in the Aberdeen Cod fishery. The Scottish pearl fishery continued till the end of last century, especially in the River

Tay, where the Mussels were collected by the peasantry before harvest time. The pearls were usually found in old and deformed specimens. Round pearls, about the size of a pea, perfect in every respect, were worth £3 or £4. An account of the Irish pearl fishery was given by Sir R. Redding, in the *Philosophical Transactions*, 1693. The Mussels were found set up in the sand of the river-bed, with their open side turned from the torrent; about one in a hundred might contain a pearl, and one pearl in a hundred might be tolerably clear.



UNIO PICTURUM.

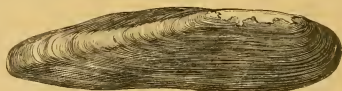
Chinese employ to produce artificial pearls, by the introduction of shot, &c., between the mantle of the animal and its shell. A *Hyria* in the British Museum has a number of little josses made of bell-metal, now completely coated with pearl, in its interior. The river Mussels are found in the ponds and streams of all parts of the world. In Europe the species are few, though specimens are abundant; in North America, both species and individuals abound. All the remarkable generic forms are peculiar to South America and Africa.

Genus *Anodon*. The shell is thin and toothless. This is the largest of European fresh-water molluscs. It has a very inflated shell; the valves, although toothless, are united by a strong external ligament; the foot of the animal is very large, and of an orange-yellow colour. The lakes, canals, ponds, and gently-flowing rivers through Europe, are all tenanted by *Anodonta*. They are very abundant in North and South America. Several hundred species have been described, but they are, in all probability, capable of being reduced to half a dozen, so great are the variations which these shells present.

Nearly all the great rivers of the world have some characteristic form of the genus *Unio*. Thus *Castalia* is peculiar to the rivers of South America, especially the Amazon. *Iridina* occurs in the rivers of Africa, as the Nile and Senegal. *Mycetopus*, a *Solen*-like form of *Unio*, is found in South America only.

Two genera (*Etheria*), from the River Nile (first noticed by the African traveller Bruce as a "fresh-water Oyster"), and *Mülleria*, from New Granada, are fixed and irregular when adult, and have been placed with the *Chamas* and Oysters by the admirers of artificial systems; fortunately, however, M. D'Orbigny has ascertained that the *Mülleria*, which is fixed and mono-myary when adult, is locomotive and di-myary when young, like any other *Unio*. (S. P. Woodward).

Mollusca inhabiting fresh water are especially exposed to corrosive action, either from carbonic acid in solution or dilute sulphuric acid from the decomposition of iron pyrites. But the action is especially manifested in those stagnant waters where the first probe of the collecting-rod disengages



ANODONTA ENSIFORMIS.

* Latin, *unio*, a pearl.

from the mud an abundant stream of bubbles of sulphuretted hydrogen. In such situations the spiral shells—for example, *Bithynia*—have lost the ends of their spires, and the discoidal shells, like *Planorbis*, have been found with a small hole caused by the dissolution of the inner whorls. The great and ponderous Mussels of the American rivers, and even the fresh-water *Unios* and *Anodons* of British streams, are often externally eroded, and the cause has been the subject of much speculation. The umbo is the part first formed, and consequently that where the epidermis is thinnest and has been longest exposed to the action of the elements, and it is this portion of the shell which is most corroded.

Division b. SIPHONIDA.—In this section the animals have respiratory siphons, and the lobes of the mantle are usually united. In the first subdivision the siphons are short and the pallial border is simple.

FAMILY IX.—CHAMIDÆ.

The shells in this family are thick, the valves unequal, the hinge teeth two in one valve and one in the other; the ligament is external.

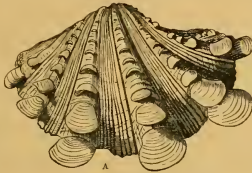
Genus *Chama*. These shells are found only in tropical seas among coral reefs. They are attached indifferently by either valve. When the right valve is fixed the dentition is reversed, the left valve having the single tooth. The exterior of the valves is ornamented with a succession of brightly-coloured frills.

FAMILY X.—TRIDACNIDÆ.

The valves are strongly ribbed and toothed at the margin, the hinge ligament is external, the shells are equal. Sometimes the animal is attached by a byssus, in others it is free.

The genus *Tridacna* is the largest of the whole class of bivalves. The Giant Clam (*Tridacna gigas*) of

the Indian Ocean, the shell of which often weighs upwards of 500 lbs., contains an animal weighing sometimes 20 lbs., which is stated by Captain Cook to be very good eating. Darwin, in his "Voyage of a Naturalist



TRIDACNA SQUAMOSA—A, OUTSIDE, AND B, INSIDE OF SHELL.

Round the World," in describing Keeling Atoll says—"We stayed a long time in the lagoon, examining fields of coral and the gigantic Clam-shells, into which if a man were to put his hand he would not as long as the animal lived be able to withdraw it." The Paphian Venus, springing from the sea, is usually represented as issuing from the opening valves of a *Tridacna*. The huge valves of this shell are frequently used for holy water in churches. Two weighing 500 lbs. and measuring more than two feet across may be seen in the church of S. Sulpice, Paris. (Dillwyn.)

FAMILY XI.—CARDIADÆ.

The Cockles live unattached; their valves are equal and nearly bilaterally symmetrical; the surface of the shells is ribbed radially; the siphons are short; there are two gills on each side. the foot is large and recurved.

In *Cardium* the shell is inflated, the umbones prominent; the hinge has two lateral teeth, one in each valve. The margins of the valves are crenulated. The common Cockle (*Cardium edule*) is largely used in many parts of England for food. It is obtained at extreme low water on all sandy shores, living buried in the sand. It ranges from the Baltic southward, and is found in the Black Sea and Caspian. Two other much larger species occur on the British coast, viz., *C. rusticum*, and the Prickly Cockle (*C. aculeatum*). Both of these are edible, but the small species is the one so largely consumed in all parts of Britain.

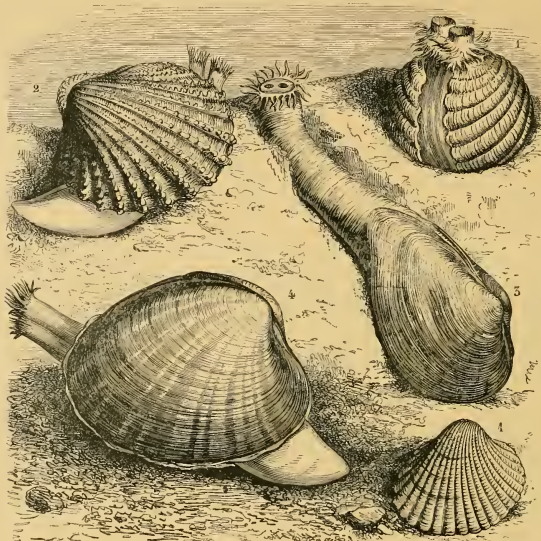
FAMILY XII.—LUCINIDÆ.

The valves of the shell of this family are circular, closely fitting, and unattached; the surface of the shell is dull; the foot is long and cylindrical.

The shell in the genus *Lucina* is white, the umbones of the valves small and compressed. The margins of the shell are smooth or finely crenulated; the ligament is concealed, the hinge teeth are lateral. The foot is often twice as large as the animal.

The *Lucina* occur in tropical and temperate seas, on both sandy and muddy bottoms, from low water to near 200 fathoms.

In *Corbis* the valves of the shell are elegantly sculptured concentrically, and the margins finely toothed within. Five species occur in the Indian and Pacific Oceans. In *Diplodonta* the shell is very like *Lucina*, but with a rather long double ligament, and two hinge teeth. Their distribution



1, *CARDIUM EDULE*; 2, *CARDIUM ECHINATUM*; 3, *MYA ARENARIA*; 4, *CYTHEREA CHIONE*.

is world-wide. *Ungulina* has a more oblong form than *Diplodonta*, with a short ligament and thick epidermis. It burrows in coral, and is found in Senegal and the Philippines. The minute orbicular shell of the genus *Kellia* is very thin. The animal creeps freely, and fixes itself by a byssus at pleasure. One species (*K. rubra*) is found in crevices of rocks at high water; others range to a depth of 200 fathoms in Norway, New Zealand, and California. Genus *Montacuta*, another small form, walks freely on a large and broad foot, and attaches itself to the spines of the Purple-heart Urchin; others burrow into the valves of dead shells. *Lepton* has a thick tapering foot, forming a creeping disc. The mantle extends beyond the shell, bearing a fringe of filaments. Genus *Galeomma* has a thick fibrous epidermis. The foot is long and narrow, with a flat sole. It spins a byssus, which it breaks at will, and creeps about like a snail, spreading out its valves nearly flat.

FAMILY XIII.—CYCLADIDÆ.

The animal has a thin, horny shell, with the mantle lobes partly open for the passage of a large protruded foot, and united posteriorly to form the branchial and excurrent siphons, which are prolonged into tubes wholly or partially united.

In *Cyclas* the animal is ovo-viviparous. The gills are large, the valves of shell are nearly equal, and much inflated. The young of *Cyclas* are hatched in the gills of the parent. They vary in size from one-sixth to one-quarter the length of the mother. They are very active, climbing in aquatic plants, attaching themselves by delicate threads. They chiefly inhabit the temperate regions of the globe in both hemispheres.

The shells of *Cyrena* are covered with a rough epidermis; they are oval and thick, and have three hinge teeth, and one lateral tooth in each valve; the foot is strong and tongue-shaped. This mollusc is found abundantly in the Nile and other Eastern rivers to China, and in mangrove swamps, usually near the coast. It is particularly interesting to geologists, being found in the old river deposits of the Thames, &c., associated with the remains of elephants, &c.

FAMILY XIV.—ASTARTIDÆ.

The characters in this family are, shell free; oblong or nearly round; surface of valves often concentrically ribbed, and covered with a brown epidermis; hinge with strongly developed cardinal teeth. All the genera are marine.

The shell of *Astarte* is thick; the valves are somewhat round, and compressed towards the beaks; they are smooth or concentrically furrowed; there are two hinge teeth in each valve; the hinge ligament is external. Of the twenty species known, by far the larger number are Arctic, being met with by the Polar expeditions, both living and as dead shells, on raised beaches far above the present level of the sea.

Genus *Crassatella*. The shell is oblong, attenuated behind; the valves are very thick, smooth, or furrowed concentrically; the ligament is internal; the muscular impressions are deep, rounded, distinct; the mantle line is simple. Thirty-four species are living in Australia, the Philippines, Africa, &c.

FAMILY XV.—CYPRINIDÆ.

About half of this family are fossil, and the rest were more abundant in the Tertiary period than at the present time. The valves are equal, round, or elongated, solid, closely-fitting, with a thick dark epidermis; the hinge ligament is external; there are hinge teeth, one and three in each valve; the mantle border is simple.

In *Cyprina* the shell is large and strong, oval in outline. Like *Astarte*, *Cyprina* has an extreme northern range from Britain to Iceland, and northward as far as the explorers have advanced towards the Pole.

The genus *Circe* has a thick, compressed orbicular shell, ornamented with diverging striæ; the valves are compressed, and the umbones flat; hinge teeth three and three. Forty living species are found in Australia, India, the Red Sea, Britain, &c.

In the "Heart Cockle" (*Isocardia*) the valves are smooth, inflated; the umbones are distant, and somewhat spiral; the hinge ligament is external; hinge teeth two and two, lateral teeth one and one, in each valve. It burrows in the sand. Five species are living in the Mediterranean, China, and Japan.

Cypricardia dwells in the crevices of rocks and coral, and is found in the Red Sea and Indian Ocean.

In *Cardita* the hinge ligament is external, the margins are toothed, the hinge teeth are one and two; the shell is narrow and oblong, and radially ribbed. Fifty-four species are found living, chiefly in tropical seas. It had a more extensive distribution in past geological times.

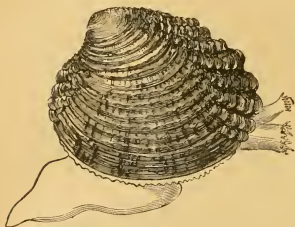
In Subdivision 2 the animals have long respiratory siphons, and the pallial border is recurved.

FAMILY XVI.—VENERIDÆ.

These bivalves are free, and do not live attached to other bodies by a byssus, nor do they bore into rocks, but live simply in sandy or muddy sea-bottoms, into which they burrow by means of their tongue-shaped foot. The siphons are unequal—retractile; the hinge ligament is external; the shell is regular and closely fitting, more or less circular or oval in outline, with three teeth in each valve. The shells of this family are hard, solid, and generally marked by elegance of form and coloration.

In *Venus* the mantle margins are fringed; the siphons are unequal and separate; the shell is thick

ovate, and tumid, the valves grooved or lamellate; the margins of the shell finely crenulated; the lunule is distinct, the hinge thick, with three teeth in each valve; line of the mantle has a short angular bend. One hundred and seventy-six species of this genus are found living, with a world-wide distribution, in the

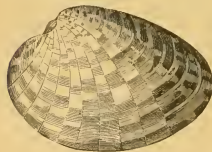


VENUS VERRUCOSA, WITH ITS ANIMAL.

Genus *Artemis*. At first sight *Artemis* looks like a *Lucina*, but the outline is almost circular, and it has a deep angular pallial fold; the hinge is like *Cytherea*; the foot is large and hatchet-shaped; the siphons are united; the margin of the mantle is plaited. *Artemis* ranges from northern to tropical seas, and from low water to 100 fathoms. One hundred species are known.

Genus *Lucinopsis*. The shell is less elegant in outline than in *Artemis*, and thinner; the right valve has two diverging teeth, the left has three; the mantle-fold is very deep; the siphons are longer than the shell, and diverge from one another; their orifices are fringed. Ten species are living in North America, Norway, the Mediterranean, and Britain. It is also found fossil.

Genus *Tapes*. The outline of the shell is ovate, oblong; the umbones of the shell turned forward; the margin smooth; the siphonal fold deep and rounded. The animal is eaten in North America and on the coast of Europe; it lives burrowed in the sand from low water to 100 fathoms. Nearly eighty species are known living.



CYTHEREA MACULATA.

the valves are covered with a dark green epidermis; the siphons are very long. Twelve species are living near the mouths of rivers in India, China &c.

FAMILY XVII.—MACTRIDÆ.

The *Macrida* have somewhat triangular equal valves, mostly close fitting; they have a deep pit for the hinge ligament, triangular in form; the hinge has two diverging teeth; the siphonal fold is short and rounded; the epidermis is thick.

*Macra** has a large tongue-shaped foot; the siphons are united and fringed; the shell is

* Latin, *maetre*, a kneading trough.

British Islands, North Sea, Mediterranean, Cape of Good Hope, &c. They are found buried a few inches deep in sand at low water, and range to 100 fathoms; they are all edible. The North American Indians used to make coinage ("wampum") of the sea-worn fragments of *V. mercenaria* by perforating and stringing them on leather thongs. Long Island was called *Seawar huckee* (or Shell Island) by the Moheyan Indians, who resorted to it to collect Seawan ("wampum shells"), from which they made their purple beads. *V. mercenaria* ranges from Cape Ann, Mass., to Delaware Bay; it is called the "round clam"—"quahog." It sells from 37½ to 62½ cents the bushel.

Genus *Cytherea*. The shell is like *Venus*, but the margins are smooth; the border of the mantle is plain, and the siphons are partly united. One hundred and thirteen species are living.



CYTHEREA GEOGRAPHICA, WITH ITS ANIMAL.

The genus *Venerupis* lives in crevices of rocks; the shell is oblong and ornamented with concentric raised lunellæ, and striated radially. Twenty species are living in Britain, the Canaries, India, Peru, &c.

The genus *Petricola* burrows in limestone and mud; the shell is oval and thin. Thirty species are living in the United States, New Zealand, &c.

Genus *Glaucomya*. The shell is shaped like a *Mya*, but with three teeth in each valve. The siphonal fold is deep and angular;

nearly equilateral. The Mactras inhabit sandy coasts, burrowing just below the surface. Mr. Alder says that in the island of Arran *M. subtruncata* is collected at low water to feed pigs on; they are also eaten by the Starfishes and Whelks. One hundred and twenty-five species are known living. They are world-wide in their distribution, being especially abundant within the tropics.

The shell of *Gnathodon* closely resembles that of *Cyrena* in form, the valves being thick and smooth, and covered with a green epidermis; the hinge has two teeth and a deep central cartilage pit; the siphonal fold is moderately deep. Sir Charles Lyell mentions that *G. cuneatus* was formerly eaten by the Indians. At Mobile, on the Gulf of Mexico, it is found with *Cyrena carolinensis* burrowing two inches deep in mud. The water is brackish, though there is a tide of three feet. The city of Mobile is built on one of these shell-banks. The road from New Orleans to Lake Pontchartrain is made of *Gnathodon* shells procured from the lake, where there is a mound at the east end a mile long and fifteen feet high, and twenty to sixty yards wide.*

The genus *Lutraria* has a very oblong shell, open at both ends; it has a prominent cartilage pit and two small teeth in each valve; the fold for the siphons is deep and round; the foot is large and compressed; the shell is covered with epidermis. It inhabits the mud of estuaries. Eighteen species are known, widely distributed.

The genus *Anatinella* has an ovate shell; the cartilage is in a spoon-shaped process within the valves; there are two small hinge teeth; the pallial line is nearly entire. Three species are living in Ceylon and the Philippines.

FAMILY XVIII.—TELLINIDÆ.

The shell has equal valves, closed and compressed; the cardinal teeth are two; the siphonal fold is large; the foot is tongue-shaped; the siphons are separate, long, and slender. "The Tellens are found in all seas, chiefly in the littoral and laminarian zones; they frequent sandy bottoms or sandy mud, burrowing beneath the surface; a few species inhabit estuaries and rivers. Their valves are often richly coloured and ornamented with finely sculptured lines." (S. P. Woodward.)

Genus *Tellina*. The shell is ovate, oblong, rounded in front, angular behind; the valves smooth or marked with radiating striae. The most beautifully coloured *Tellinæ* are found in the seas of tropical regions. The animals have the power of leaping from the surface by means of their muscular foot. More than 300 species have been described.



TELLINA RADIATA.

Genus *Gastrana*. The shell is triangular, valves equal and convex; there are two cardinal teeth in the right valve and one in the left; the siphonal fold is deep and rounded. *Gastrana* bores in mud and clay, and does not move about freely like *Tellina*. Three species are known from South Africa.

Genus *Capsula*. The shell is ovate, long, open at each end; it is striated radially; there are two hinge teeth in each valve; the animal resembles *Psammodia*, but the siphons are shorter. Four species are living in the West Indies, China, &c.

Genus *Psammodia*†, "Sunset shell." The surface of the valves is smooth or radiately striated, the siphons very long and slender. They inhabit sand and mud, and range from the littoral zone to a depth of 100 fathoms. A few inhabit British shores, and others with very delicate and beautifully-rayed shells are natives of the Pacific and Indian Oceans, &c.

Genus *Sanguinolaria*. The shell is ovate oblong, round in front, attenuated and gaping behind; the pallial fold is very deep; the hinge ligament external; the teeth small, two in each valve; the siphons very long; the foot large and tongue-shaped. Twenty species are found living in the West Indies, Australia, Peru, &c.

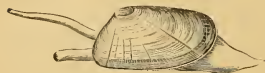
The genus *Semele* has a shell like a *Tellina* in shape, with two hinge teeth in each valve, the

* "Second Visit to the United States," vol. ii., p. 106.

† Greek, *psammos*, sand; *bios*, life.

ligament is external and short, the cartilage internal and long, the siphonal fold deep. Sixty species are known from Brazil, India, China, &c.

Genus *Mesodesma*.* The valves of shell are thick, triangular, closed; the ligament is internal; there are lateral teeth in each valve; the siphonal fold is small; the muscular impressions are deep. Thirty-one species occur in the West Indies, Chili, and the Mediterranean.



DONAX TRUNCULUS.

In the genus *Donax* the shell is wedge-like, somewhat triangular, rounded in front, truncated behind; the border of the valves is crenulated; there are two hinge teeth in each valve, and the ligament is external. Sixty-eight species are known, found living in Norway, the Baltic, &c.

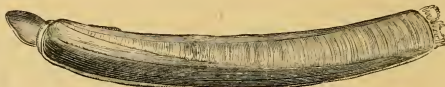
The genus *Galatea* has a very thick, wedge-shaped, triangular shell, with an olive-green epidermis; the hinge is strong, with three teeth and an external prominent ligament, the siphonal fold is distinct. This is a fresh-water shell, inhabiting the rivers of Africa. Six species are known.

Genus *Ercillia*, "Lentil-shell." The shell is oval and small, with a single prominent tooth to the hinge in right valve, and two obscure teeth in left valve. The siphonal fold is deep. Two species are living at fifty fathoms in the West Indies, &c.

FAMILY XIX.—SOLENIDE.

The shell is more or less elongated, open at each end; the hinge ligament is external; there are cardinal teeth, two in the right valve and three in the left. The *Solens* have a large and powerful cylindrical foot; the siphons are short, and the gills narrow.

Genus *Solen*, "Razor-fish." The shell is somewhat cylindrical, long and straight, or slightly curved, margins parallel, ends gaping, hinge line elongated, ligament external, foot cylindrical, obtuse. The *Solens* are of world-wide distribution, except in the colder seas. The Razor-fishes are powerful burrowers; they never willingly leave their burrows; they may, however, be caught with a bent wire, and are good eating when cooked.



SOLEN ENSIS.

Genus *Solecurtus*. The shell is ovate oblong, the umbo small, margins almost parallel, ends rounded, gaping; the hinge ligament is external; there are two hinge teeth in each valve; the siphonal fold is



SOLEN VAGINA.

very deep; the animal is entirely retractile within the shell. The *Solecurti* bury themselves in sand and mud, and are difficult to obtain alive. *S. caribaeus* occurs in countless numbers in the bars of American rivers. By removing three or four inches of sand its burrows may be discovered; they are vertical cavities one inch and a half in diameter, and twelve or more deep; the animal holds fast by the expanded end of its foot. (S. P. Woodward.) Twenty-five species are known in Britain, Africa, Madeira, the Mediterranean, &c.

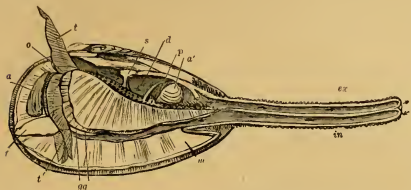
FAMILY XX.—MYACIDÆ.

The valves of the shell are gaping behind, opaque and strong, covered with a wrinkled epidermis; the mantle is almost closed; the foot small; the siphons united and retractile.

Genus *Mya*, "Gaper." The shell is gaping at the ends; the left valve smaller than the right, with a large process for the cartilage; the siphonal fold is large; the epidermis extends over and encloses the siphons, which are partially retractile. Some of the species of *Mya*, as *M. arenaria* and *M. truncata*, have a high northern range, being found through the Arctic seas; they are considered excellent food, and are not only eaten by man, but by the walrus, the Arctic fox, and even by birds. Ten species are known living.

* Greek, *mesos*, middle, and *desmos*, ligament.

Genus *Corbula*. The valves of this shell are very unequal, and produced behind; they do not gape; the right valve, which is the largest, has a prominent tooth in front of the cartilage pit; the smaller left valve has projecting processes; the siphons of the animal are short and united, the foot is pointed. There are sixty species living. It inhabits the lower laminarian zone, and dwells in eighty fathoms.



ANATOMY OF SOFT PARTS OF MYA ARENARIA.

a, the Anterior, and a', the Posterior Adductor Muscle; ex, the Excurrent, and in, the Incumbent Siphon; g g, the Gills, or Braehia; f, the Foot; tt, the Labial, or Lip-tentacles; o, the Oral Aperture, or Mouth; s, the Stomach; d, the Intestine opening into the Excurrent Siphon; p, the Pedal, or Foot, Muscle; m, the Mantle.

the valves are equal; they are thick, more or less oblong, and open at either end; the hinge ligament is external; there is a prominent tooth in each valve; the siphonal indentation is deep. This is an Arctic form, extending from the White Sea to Norway and Britain. The Panopeas are great burrowers; they dwell from low water to 100 fathoms. The shell attains a length of six or eight inches. Eleven species are found living in the North Sea, Mediterranean, &c.

Some of the British shells fetch high prices on account of their rarity, although their appearance is by no means attractive. The rude-looking bivalve called *Panopea norvegica* cannot be obtained for less than three guineas; and there is an unusually good specimen in the collection of Mrs. De Burgh, which was offered to the British Museum for six guineas and declined, but afterwards realised nearly that amount. *Tellina balaustrina* is a much smaller but brightly-tinted shell, of which there is a specimen in the British Museum worth three guineas.

FAMILY XXI.—ANATINIDÆ.

The *Anatinidæ* have thin, nacreous, inequivalve shells, with an external ligament and an internal cartilage; the siphons are long and united; the gills are single on each side. A large proportion of this family only occurs fossil.

Genus *Anatina*, "Lantern-shell." The hinge is provided with a spoon-shaped cartilage process in each valve; the siphons are long, united, covered with wrinkled epidermis; there is one gill on each side; the foot is very small. Fifty species are found living in India, West Africa, the Philippines, and New Zealand.

Genus *Thracia*. *Thracia pubescens* and *Anatina subrostrata*, and its sub-genus *Periploma pretenue*, are all closely allied forms of the family *Anatinidæ*. There are seventeen species of *Thracia*, extending from Greenland to the Canaries and China, living at a depth of from four to 120 fathoms.

Genus *Pholadomya*. The shell is transversely oblong, equivalve, thin, white, and translucent, gaping at both ends, pearly inside; the surface of the valves is ornamented with radiating ribs. Although 160 species are known fossil, only one recent form is known, which is occasionally met with on the shores of the Island of Tortola, in the West Indies, after hurricanes, being probably thrown up from deep water by the force of wind and waves.

Genus *Lyonsia*. The valves of this shell are thin, somewhat pearly, the left being a trifle the larger; the posterior end is truncated; the cartilage plates are oblique; the animal has a tongue-shaped foot, which is grooved, and spins a byssus. Twelve species are known, ranging from Greenland to Madeira and the Indian seas.

Genus *Pandora*. This genus has thin, closely-fitting valves, pearly inside; the right valve is flat, with a diverging ridge and cartilage; the left valve is deep, with two diverging grooves at the hinge; the foot is narrow, and the siphons very short. Eighteen species are known living, ranging from Spitzbergen to Panama, India, &c.

Genus *Myadora*. In *Myadora* the valves are exactly the converse of *Pandora*, the left being flat and the right convex. The outline is more triangular than that of *Pandora*, and there is a free sickle-shaped ossicle in the right valve and two tooth-like ridges in the left. Ten species are found living in New Zealand, New South Wales, and the Philippines.

Genus *Myochama*. In *Myochama* the animal is attached by the right valve, while the left is round; the cartilage is internal; there are two tooth-like projections in each valve. It is attached to *Trigonia* and *Crassatella*. Its habitat is New South Wales.

Genus *Chamostrea*. The shell is solid, and attached by the front side of the right valve, which is deep and strongly keeled. One species only is known, from New South Wales.

FAMILY XXII.—GASTROCHLENIDÆ.

They have thin, gaping, toothless valves, united by a ligament, and cemented to a shelly tube when adult. The animal has two very long united siphons behind, and a truncated finger-like foot in front. The members of this family are burrowers, either in mud or stone, near low water.

Genus *Gastrochlena*.* The shell is wedge-shaped, the umbones are turned forward, the valves gape widely in front and are closed behind. *Gastrochlena* perforates shells and limestone; its holes are regular, about two inches deep; the external orifice is hour-glass-shaped and lined with shell. Ten species are known in the West Indies, Britain, Red Sea, Pacific Isles, Panama, &c.



THE WATERING-
POT SHELL,
ASPERGILLUM.

Genus *Saxicava*. The young shell is said to be symmetrical and furnished with two teeth in each valve; but the adult is rugose, toothless, thick, oblong, gaping, with an external hinge ligament; the siphons are large and united near the ends. So variable is this shell that five genera and fifteen species have been named upon its aberrant forms. It conceals itself in the crevices of rocks and coral and amongst the roots of seaweed. At Harwich it bores into the Clay ironstone, at Folkestone into the Kentish Rag, and at Portland into the Portland Oolite. Its crypts are six inches long. *Saxicava* ranges from low water to 140 fathoms; it is found in all Arctic seas. Specimens of *Saxicava arctica* were more abundant than any other shells brought home by the *Alert* and *Discovery* from the Arctic regions. Among this section of mollusca are some instances which present the phenomenon of an extensive geographical distribution, though their capabilities for locomotion are very limited. For instance, some species of *Saxicava arctica*, *Venus pullastra*, and *Pecten pusio* are found both on northern shores and at the Cape of Good Hope, though not in the intermediate tropical regions. The species of *Limacina* which belongs to the South Polar Ocean cannot be distinguished from the *Limacina arctica* belonging to the North; it has no representative in the intermediate seas. The same is the case with the genus *Puncturella*, which embraces two species, of which the one belongs to the Arctic, the other to the Antarctic Seas, in the neighbourhood of Tierra del Fuego.

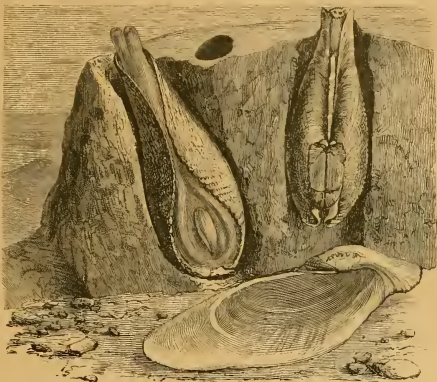
Genus *Clavagella*. In this genus the shell is oblong, irregular; the valves unequal, the right valve always free, the left embedded in the dilated hind part of the tube, which is shelly, cylindrical, attenuated, and open behind; the margin is simple or furnished with siphonal fringes. The anterior or lower end of the tube is club-shaped and either simple or surrounded by spine-like tubes; the mantle being furnished with tentacular processes forms these branching tubuli. Most of the *Clavagella* burrow in stone and coral. Six species occur in the Mediterranean, Australia, and the Pacific.

Genus *Aspergillum*, "Watering-pot Shell." In certain boring and burrowing bivalves, as *Gastrochlena*, *Clavagella*, and *Teredo*, the shell does not increase with age, but the siphons secrete a shelly tube in which the soft parts of the animal are encased, and the minute valves of the young mollusc are seen embedded in the wall. In *Aspergillum vaginiferum*, the Watering-pot Shell, the minute valves are also to be seen near the lower extremity of the tube, the siphonal end being plain, or ornamented with from one to eight frills. Twenty-one species occur in the Red Sea, Java, New Zealand, &c.

* Greek, *gaster*, belly, and *chena*, gape.

FAMILY XXIII.—PHOLADIDÆ.

The characters of this family are, shell free, or within a tube; valves equal, gaping at both ends, thin, white, brittle, armed in front with rasp-like imbrications, without hinge teeth, and strengthened externally by accessory valves; hinge-plate reflexed over the beaks, and furnished with a long, curved muscular process beneath each; anterior muscular impression on the hinge-plate, pallial sinus very deep. It lives perpendicularly in holes in the rock or sand. The *Pholadidæ* perforate all substances that are softer than their own valves (M. Cailliaud), but Mr. Hancock has pointed out that the foot appears to be a more efficient instrument than the shell for burrowing into rock, seeing that its surface can be renewed as fast as it is worn away.



PHOLAS DACTYLUS IN A SHELTER HOLLOWED OUT BY IT IN A BLOCK OF GNEISS.

Genus *Pholas*. The common Piddock is used for bait on the coast of Devon; its foot is white and translucent when fresh. It has two accessory valves to protect the umboval muscle, with a small transverse plate behind; a long unsymmetrical plate fills up the space between the valves in the dorsal region. Thirty-two species are found living at twenty-five fathoms. It is almost cosmopolitan. *P. costata* is sold as food in the market of Havannah.

Genus *Pholadidea*. This genus resembles *Pholas*, but has a deep transverse furrow across the centre of its valves; the anterior gape is large, but closed in the adult by a callous plate. Seven species are found, from low tide to ten fathoms, in Britain, New Zealand, and Ecuador. *Pholadidea* and its sub-genera burrow into shell, wood, resin, wax, &c.

Genus *Xylophaga*. This genus bores into floating wood and timbers which are always covered



TEREDO NAVALIS.

by the sea. Two species are living in Norway, Britain, and South America.

Genus *Teredo*.

The shell is globose, gaping anteriorly, and behind; the

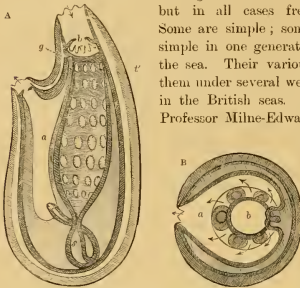
valves are trilobate, concentrically striated, divided by a single transverse groove; the hinge margins are inflexed anteriorly; the interior of the valves is furnished with a long, curved process for the attachment of the pedal muscle. *T. navalis* is ordinarily a foot long, sometimes two feet and a half; it destroys soft wood rapidly, and teak and oak do not escape; it always bores in the direction of the grain, unless it meets another *Teredo*. In 1731-2 it did great damage to the piles in Holland, and caused still more alarm; metal sheathing and broad-headed iron nails have been found most effectual in protecting piers and ship-timbers. The *Teredo* was first recognised as a bivalve mollusc by Sellius, who wrote an elaborate treatise on the subject in 1733. (Forbes.) Fourteen species occur living from low water to more than 100 fathoms, in Norway, Britain, and the Tropics.

HENRY WOODWARD.

INVERTEBRATA.—INTERMEDIATE TYPE. THE TUNICATA.

Structure of the Tunicata Explained—The Throat or Gullet serving as the Breathing Organ—Curious Ebb and Flow of the Blood—Their Division into Simple, Social, and Compound Ascidians—Known to Aristotle—1. SIMPLE ASCIDIANS—Muscular Nature of Tunic—"Sea-Squirts"—Where Found—2. SOCIAL ASCIDIANS—Mode of Union—Genera—3. TRUE COMPOUND ASCIDIANS—Their Anatomy—4. THE PYROSOMIDE—Their Pelagic Habits—Their Phosphorescence—5. SALPIDE—Pelagic—Solitary or in Chains.

THE Tunicata are enveloped in a coriaceous (or leathery) tunic or mantle; whence their name. This is constructed in the form of a sac with two openings, or else in the shape of a tube of greater or less dimensions, open at both ends. Within the tunic are the viscera, consisting of well-defined organs of respiration, circulation, and digestion, and a muscular and a nervous system. The branchial organ is usually in the form of a sac, placed at the commencement of the alimentary canal, of which it forms, as it were, the ante-chamber, and is never arranged in distinct leaflets, as it is in the leaf-gilled bivalve Mollusca. The circulation of their blood is remarkable on account of its fluctuations and periodical changes of direction. They have no distinct head, and no organs serving as arms or feet. Sometimes they are free, more usually fixed, but in all cases free during the earlier portion of their existence. Some are simple; some present various degrees of combination; some are simple in one generation, combined in another. They are all dwellers in the sea. Their various states and structures enable naturalists to group them under several well-marked tribes, of most of which we have examples in the British seas. The best classification of them is that proposed by Professor Milne-Edwards. He divides them into three sub-orders, of which



STRUCTURE OF TUNICATE—A, VERTICAL; B, TRANSVERSE SECTION.

a, the Atrial or Excurrent Chamber; b, the Branchial Sac; s, the Stomach; t, the Test; f, the Muscular Coat or Mantle; g, Nervous Centre. The Arrows indicate the direction of the Currents.

the *Saba*, the *Ascidia*, and the *Pyrosoma* are the types, and subdivides the Ascidiens proper into simple, social, and compound. Of all, except the *Pyrosoma*, there are British examples.

"These animals attracted the notice of the all-observing Aristotle. Like most philosophic naturalists, the question of the distinction between the animal and vegetable kingdoms had for him great attractions. The Ascidian was one of the many creatures which he examined, in the hope of gaining definite information respecting such distinction. Its inert and sponge-like form, rooted to the ground, seemed to indicate a vegetable nature;

but Aristotle was not content with a mere external survey. He explored its internal structure, and soon perceived its highly animal condition. His description of the Ascidia is wonderfully correct; it occurs in the fourth book of his 'History of Animals.' There he distinctly recognises the Ascidiens to be Mollusca, of which he says 'they are the only kind whose whole body is enclosed in a shell, and that shell of a substance between true shell and leather; it may be cut like dry leather.' What comparison could be more graphic or more true? 'They are attached to rocks by their shell. They have two separate openings, which are very small and difficult to notice, one to take in and the other to eject the water. . . . If we open them, we find a nervous membrane lining this leathery case, and fixed to it at two points corresponding to the openings, one of which may be looked upon as the mouth, the other the vent.' And then he makes further remarks on their anatomy. His appreciation of the nature of the Ascidiens is an interesting proof of the wonderful sagacity and minute observation of the great Father of Natural History." (Forbes and Hanley, "British Mollusca.")

FAMILY I.—ASCIDIADÆ (SIMPLE ASCIDIANS).

The body is sac-shaped, gelatinous or leathery, fixed at one extremity and free at the other; it has two more or less prominent orifices, one the "oral," or mouth-opening, the other the "atrial," or excurrent aperture. The simple Ascidiens are *not* united into groups by a common integument; but at times

they are met with as gregarious assemblies of individuals, and at others as solitary examples. They are oviparous, and the sexes are united.

On the coasts of the Channel, the Mediterranean, and in the China seas and in Brazil, some of the species of these simple Ascidians are valued as articles of food. "At Cette, *Ascidia* are taken regularly to market, and *Cynthia microcosmus*, although so repulsive externally, furnishes a very delicate morsel much sought after." (Van Beneden.) The young Ascidians commence life as free-swimming, tadpole-like embryos. The tadpole as it appears in the egg is at first an oval disc; a tail is soon after observed; arm-like projections spring from the head of the creature, which then presents a striking analogy with the form of a hydroid Zoophyte; it becomes free, and swims about by means of its rapidly vibrating tail; it fixes itself to rocks and seaweeds by its arms; the tail disappears; that which was the head, or nucleus, sends out root-like projections, orifices appear in it, and its final form as an Ascidian begins to be manifested.

The characters of the genus *Ascidium** are—body sessile, covered with a leathery or gelatinous tunic; branchial orifice eight-lobed; atrial orifice six-lobed; branchial sac not plicated, having a circle inside of simple tentacular filaments; the meshes of respiratory sac papillated.

The leathery sac is exceedingly muscular and contractile, and from the rapidity with which (when touched) they eject the water contained in their bodies, they are popularly known as "Sea-squirts." This outer covering is very remarkable as containing a considerable proportion of a substance apparently identical with cellulose, which is one of the most characteristic of all vegetable products.

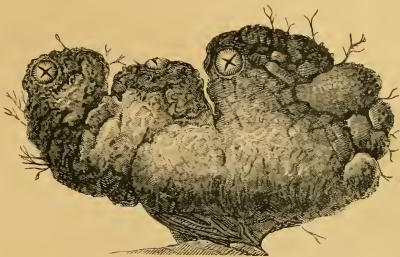
The Ascidia are found attached to the under side of rough stones, and vary in length from one to six inches. They are variously, often splendidly, coloured, but are otherwise unattractive. Numbers of them are often found clustering among tangles, like bunches of some strange semi-transparent fruit. (E. Forbes.)

They range from low water to twenty fathoms, attached to rocks, shells, and the like, twenty species being found in Britain, the Mediterranean, Greenland, Spitzbergen, the United States, and elsewhere.

Genus *Molgula*.† The body is attached or free, and more or less globular in form; the orifices are very contractile naked tubes; the oral is six-lobed, the atrial four-lobed. They have been met with between tide-marks in the laminarian zone, and down to a depth of twenty-five fathoms. The surface is membranous, and is usually covered with particles of sand and other extraneous substances. Five species are recorded by Adams, from Britain, Denmark, &c.

Genus *Cynthia*. The body is covered with a coriaceous tunic, not stalked; the oral and atrial orifices are each four-lobed; the branchial sac is longitudinally plicated. The meshes in the respiratory tissue have no papillae; there are two ovaries. The species ranges from low water to thirty fathoms. They are frequently found associated in groups of numerous individuals, and their tests, even in the same species, are often variously coloured. They are found on the coast of Greenland, Norway, Britain, and the Mediterranean. They are often gregarious, forming large bunches by the interlacing of their root fibres.

Genus *Peloniaia*.‡ The test is cylindrical; the body elongated, smooth or wrinkled; the apertures are on two small conical eminences, lower end provided with fine rootlets; there are two ovaries. Two species occur in Britain and Norway. *Peloniaia* resembles *Sipunculus*, one of the worm-like Echinoderms, in appearance; it is not free, but rooted in the mud, and quite as apathetic as other Ascidians.



CYNTHIA (ASCIDIA) MICROCOSMUS.

* Greek, *askos*, a skin bottle.

† Greek, *molygos*, a bag of skin.

‡ Greek, *pelos*, mud; *naio*, to inhabit.

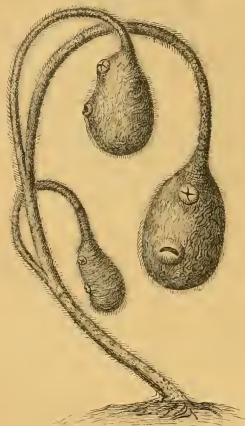
The characters of the genus *Chelyosoma** are—covering horny; form oblong, depressed; upper surface covered by eight polygonal plates; aperture small, six-valved, prominent. Its habitat is Greenland.

Genus *Boltenia*. These Ascidians have a horny covering, and are attached by a stalk, the young growing on the stem of the parent. The apertures are on the side; they live attached to stones in deep water, sometimes as much as seventy fathoms. Six species are enumerated from New Zealand, Greenland, and North America; they are most abundant in Arctic seas.

FAMILY II.—CLAVELLINIDÆ (SOCIAL ASCIDIANS).

The members of this family are compound, *i.e.*, each individual has its own heart, respiratory system, and organs of nutrition, but fixed on stalks or bases common to the group, through which the blood circulates in opposite directions, like the ebbing and flowing of the sea.

Genus *Clavellina*.† The body is elongated, erect; the covering is smooth, transparent, and marked with coloured lines. The individuals of a group are connected or united by creeping tubular prolongations from the common tunic. These are small, transparent, compound Ascidians, found adhering to stones and seaweed by means of curious root-like prolongations of their outer tunic, by which a circulation is kept up common to the entire community. They are found in Great Britain, Greenland, and the Mediterranean.



BOLTENIA (ASCIDIA) PEDUNCULATA.

Genus *Perophora*. The animal is stalked, roundish, flattened, and united by pedicles to creeping root-like tubes, part of the common tunic through which the blood circulates. *P. listeri* is a minute creature, and was discovered by Mr. Lister at Brighton. He says, "It occurs in groups consisting of several individuals, each having its own heart, respiration, and system of nutrition, but fixed on a peduncle that branches from a common creeping stem, and all being connected by a circulation that extends throughout." Mr. McAndrew and Professor E. Forbes dredged it adhering to weed on the Coast of Anglesey. "It is beautifully transparent, appearing on the weed like little specks of jelly dotted with orange and brown, and linked by a winding silvery thread." (Forbes.)

The characters of the genus *Syntethys* are—animals compound, gelatinous, orbicular, sessile; individuals very prominent; arranged sub-concentrically in the common mass; branchial and atrial orifices simple; not cut into rays.

Syntethys is a *Clavellina* with the habit of a *Diazona*. The only known species forms compact, greenish, translucent, gelatinous masses of half a foot in diameter, and nearly equal height, affixed to rocks or stones by a short base. The individual Ascidians are, when full grown, two inches in length. (Forbes and Hauley.) They are found in Applecross Sound.

FAMILY III.—BOTRYLLIDÆ (TRUE COMPOUND ASCIDIANS).

In the last family the individuals were seen to be connected by a common tunic, but in this family, the *Botryllidæ*, the separate envelopes are fused, and lose their individuality, forming a common covering in which all the Ascidians are embedded, in one or more groups. Their mouths, or branchial orifices, are simple, and each cluster is ranged round a common "atrial" or excurrent orifice.

If when walking on the sea-shore about low-water mark we turn over large stones, or look under projecting eaves of rock, we are almost sure to see translucent jelly-like masses of various hues of orange, purple, yellow, blue, grey, and green, sometimes nearly uniform in tint, sometimes beautifully variegated, and very frequently pencilled as if with stars of gorgeous device; now encrusting the

* Greek, *chelys*, a tortoise; *soma*, body.

† Latin *clavella*, a small staff.

surface of the rock, now depending from it in icicle-like projections. These are compound Ascidiæ. A tangle or broad-leaved fucus, torn from its rocky bed, or gathered on the sands where the waves have cast it after storms, will show us similar bodies, mostly star-shaped, investing their stalks, winding among the intricacies of its roots, or clothing with a glairy coat the expanse of its foliated extremities. If we keep some of these bodies alive in a vessel of sea water, we find them lie there as apathetic as sponges, giving few signs of vitality beyond the slightly pouting out of tube-like membranes around apertures which become visible on their surfaces, though a closer and microscopic examination will show us currents in active motion in the water around those apertures, streams ejected and whirlpools rushing in, indicating that, however torpid the creature may externally appear, all the machinery of life, the respiratory wheels and circulatory pumps, are hard at work in its inmost recesses. In the course of our examination, especially if we cut up the mass, we find that it is not a single animal which lies before us, but a commonwealth of beings, bound together by common and vital ties. Each star is a family, each group of stars a community. Individuals are linked together in systems, systems combined into masses. Each member of the commonwealth has its own peculiar duties, but shares also in operations which relate to the interest and well-being of the mass. Anatomical investigation shows us the details of these curious structures and arrangements, beautiful as wise. Indeed, few bodies among the lower forms of animal life exhibit such exquisite and kaleidoscopic figures as those which we see displayed in combinations of the compound Ascidiæ.

The merit of first understanding and interpreting the true nature of these curious bodies is due to Jules César Savigny, an illustrious French naturalist, whose zeal in the cause of minute investigation eventually deprived him of sight, and the world of many profound and philosophical researches.

Before Savigny's time the Botryllidæ had been confounded with Polypes, and regarded as forms of the genus *Acyonium*, to which, indeed, the masses bore a striking resemblance. The earliest distinct figures of these forms appeared in the *Philosophical Transactions* for 1757, where they were published by Schlosser; and in 1758, that curious observer Borlase gave descriptions sufficiently graphic, and rude but unmistakable figures, of several species, in his interesting folio on "The Natural History of Cornwall." The first naturalist who indicated their compound nature, and held forth a clue to their true affinities, was the famous botanist Gaertner, whose zoological observations on marine animals, communicated to and published by Pallas in 1774, are of the highest degree of merit. Gaertner, however, did not follow up his inquiries in these bodies, though to him we owe the generic groups *Botryllus* and *Distomus*. The Italian naturalist, Renieri, in 1793, had a similar obscure perception of their affinities.

The memoirs of Savigny, published in 1816, however, threw entirely new and unanticipated light on their nature. He showed that they were essentially Ascidiæ, differing from the simple forms only in being united into more or less complicated systems. The researches of Milne-Edwards "On the Compound Ascidiæ of the Channel," read before the Institute of France, 1839, have fully confirmed those of Savigny, and have also greatly extended our knowledge of these creatures. The figures given by both these naturalists are among the most beautiful and minutely accurate that have ever illustrated and adorned natural history essays. (Forbes).

Genus *Botryllus*. The animals of this genus offer no distinction between thorax and abdomen; their organs of digestion, &c., occupy the thoracic cavity, forming an ovoid mass. The branchial orifices are simple, ranged horizontally round a common cloaca, in groups of simple stars. There are ten species found in the United States and Europe.

Genus *Didemnum*.* The test is coriaceous, polymorphous, sessile and incrusting; the systems numerous, compressed, without central cavities; the individuals are scattered; the abdomen is pedunculate, and the ovary is placed by the side of the intestinal loop. It is found in Europe.

Genus *Eucolum*.† The test is gelatinous, but in other respects closely resembling *Didemnum*, save that the animals are sometimes arranged in fives (quincuncially). Its distribution is in the European seas.

Genus *Leptoclinium*.‡ The test is thin, gelatinous or coriaceous and incrusting. The individuals are irregularly grouped round common cavities. Six British species are found on roots of *Laminaria*. The colour is yellowish-white, variegated with blue.

* Greek, *dis*, double; *dennia*, a bed.

† Greek, *eu koilos*, much excavated.

‡ Greek, *leptos*, thin; *kline*, a couch.

The characters and distribution of the remaining genera may be succinctly stated.

Genus *Distomus*. Covering semi-cartilaginous, fixed, variable in form, groups numerous, generally circular, orifices six-rayed. Two species are found in Europe, Africa, and Australia.

Genus *Diazona*. Common covering gelatinous, fixed, sometimes stalked, groups prominent, ranged in circles on a concentric disc, like the petals of a flower, with the atrial cavity in the centre; the branchial orifice is six-rayed. One species occurs in the Mediterranean.

Genus *Polychinum*.* Covering gelatinous or cartilaginous, variable in form, systems numerous, convex, somewhat stellate, tunicaries, groups of individuals ten to one hundred and fifty, at unequal distances. Seven species are known in Britain, the Red Sea, India, &c.

Genus *Aplydium*. Systems numerous, prominent, annular or sub-elliptical, tunicaries three to twenty-five in single rows, equidistant from the centres, branchial orifice six-rayed. Living attached to stones, &c., in deep water. They are found in the Red Sea and Europe.

Genus *Sidnyum*. The animals of *Sidnyum* partake of the characters of *Synœcium* and *Aplydium*, resembling the former in the structure of their stomach, and the latter in their branchial apparatus. Each has an eight-toothed branchial orifice, and a simple tubular vent folded against the thorax. The ovary is pedunculated and very conspicuous at the extremity of the animal. (Adams.)

Genus *Synœcium*. Semi-cartilaginous, cylindrical, stalked, solitary or gregarious, systems circular, terminal tunicaries six to nine in a group; apertures six-rayed. Only one species is known, obtained from Spitzbergen.

Genus *Sigillina*. Covering solid, gelatinous, conical, elongated, erect on a stalk, individuals in irregular circles one above another, openings six-rayed. A single species is found living in tropical seas.

FAMILY IV.—PYROSOMIDÆ.

The animals are compound, free and pelagic.

Genus *Pyrosoma*.† The body is cylindrical, hollow, non-contractile, cartilaginous, open at one end only, and covered externally by the numerous pointed zooids, arranged in whorls; the interior is mammillated and pierced by the excurrent orifices of the tunicaries. The Pyrosomes are from two to fourteen inches long, and from half an inch to three inches in circumference. They are made up of innumerable individuals united side by side. The inhalent openings are external, the exhalent



PYROSOMA.

A, the atrial or excurrent opening.

within the tube, and the result of so many little currents discharged into the cavity is to produce one general outflow, which impels the floating cylinder, with its closed end forward, through the water.

June 15th, 1850, lat. 45° S., long. 110° W. :—"The sky was clear but moonless, and the sea calm, and a more beautiful sight can hardly be imagined than that presented from the decks of the ship as she drifted, hour after hour, through this shoal of miniature pillars of fire gleaming out of the dark sea, with an ever-waning, ever-brightening, soft bluish light, as far as the eye could reach on every side. The *Pyrosoma* floated deep, and it was with difficulty that some were procured for examination and placed in a bucketful of water. The phosphorescence was intermittent, periods of darkness alternating with periods of brilliancy. The light commenced in one spot, apparently on the body of the zooid, and gradually spread from this to the centre in all directions; then the whole was lighted up. It remained brilliant for a few seconds, and then gradually faded and died away, until the whole mass was dark again." (Huxley, *Philosophical Transactions*, Part II., 1851, p. 580.)

M. Péron first observed the phosphorescence of the Pyrosomes in a squall at sea. He says :—"Suddenly we discovered at some distance a great phosphorescent band stretched across the waves and occupying an immense tract in advance of the ship. Soon we reached the illuminated tract, and perceived that the prodigious brightness was certainly and only attributable to the presence of an innumerable multitude of animals floating on the waves. Those seen near the surface of the water perfectly resembled small incandescent cylinders of iron."

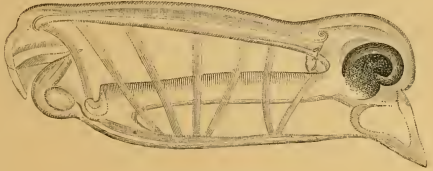
FAMILY V.—SALPIDÆ.

The animals are free, oceanic, alternately solid, and united in circular or lengthened groups. These Salpa chains vary in length from a few inches to many feet, and swim through the water with a

* Greek, *polys*, many; *kline*, a couch.

† Greek, *pur*, fire; *soma*, a body.

regular serpentine movement; but when taken from the water the individuals of the group are easily detached. Chamisso discovered that the solitary *Salpæ* do not belong to species distinct from those united in chains, however dissimilar, but are either the parents or the progeny, as the case may be, of the aggregated forms; and that chained *Salpæ* do not produce chained *Salpæ*, but solitary *Salpæ*, which in turn do not produce solitary but chained *Salpæ*, "so that a *Salp* mother is not like its daughter or its mother, but resembles its sister, its granddaughter, and its grandmother." (Chamisso.)



SALPA MAXIMA (magnified).

In the genus *Salpa** the animal is sub-cylindrical, being truncated in front by the mouth-opening, and pointed behind; the excurrent or anal orifice is placed

beneath the pointed termination; the body-covering is thin and transparent; the muscular mantle is incomplete, forming transverse or oblique bands; the mantle cavity is lined with a series of sinuses, or folds; the gill is rudimentary, forming an oblique band across the interior; the visceral cavity is behind. The young are produced by gemmation in chains, consisting of individuals unlike the parent, and becoming oviparous, the alternate generations only being alike.

"The individual Salpians are from half an inch to ten inches in length; the chains vary from a few inches to many feet, but are often broken up, indeed the adults appear to be always separate. They swim with either end foremost, although the pointed end would seem the normal one, as the motion is produced by the forcible expulsion of water from the mantle. Each orifice is furnished with a valve, and there is no division between the atrium and respiratory cavity except the rudimentary gills, or 'hypopharyngeal band.' The *Salpa*-chains also swim with a regular serpentine movement.

"The solitary *Salpæ* always contain a chain of embryos winding spirally round the visceral nucleus. The aggregate *Salpæ* produce a single ovum at a time, which is attached by a pedicle to the posterior part of the respiratory cavity." (Huxley.)

Genus *Doliolum*† The body is transparent, eask-shaped, open at the ends, and from two to ten lines in length; the oral extremity is rather prominent, with twelve denticulations; the posterior end is fringed. (Huxley.) There are two species known. They are found near Amboyna, Vanicoro, and New Zealand.

In *Appendicularia*‡ the body is ovoid, one-sixth to one-quarter of an inch long, with a long curved lanceolate tail, or swimming organ; the smaller end is perforated, leading into a cavity lined by a system of folds; the pharynx, which is ciliated, serves in lieu of a gill; the gullet is short, curved; the stomach is wide. (Huxley.)

These minute creatures appear to be the lowest forms of the Tunicata, typifying, in their adult stage, the larval state of the higher Ascidians.

"When cruising," says Prof. Edward Forbes, "off the north coast of Scotland, in 1845, with Mr. Robert McAndrew, our attention was attracted by the appearance of cloudy patches of red colouring matter in the water, and on procuring a sample, and submitting it to microscopic examination, it was found to consist entirely of the curious and anomalous creatures known as *Appendicularie*." Dr. S. P. Woodward writes:—"Many small *Appendicularie* were taken in the towing net (May, 1857) in the Channel, between Portland Bay and Ushant."

* Greek, *salpe*, a sea-fish.

† Latin, diminutive of *dolium*, a large jar.

‡ Lat., *Appendicula*, a small appendage.

THE INTERMEDIATE GROUP, MOLLUSCOIDA.

THE MANTLE-BREATHING BIVALVES (BRACHIOPODA) AND THE MOSS-ANIMALS (BRYOZOA).

THE BRACHIOPODA—Life History and Characters of the Brachiopoda—Origin of the Name—Subdivision of the Group—Its Relations to other Organisms—Growth and Structure of the External and Internal Skeleton—Muscles—Organ of Attachment—Mantle—Gills—Digestive, Generative, and Nervous Systems—How the Brachiopoda Live—Classification and Anatomy of Minor Groups—Distribution in Space and Ranges of Depth of Living Forms—Fossil Genera—Embryology and Affinities—THE BRYOZOA*—Life History of the Moss-animals—Name and Position of the Group—Its Chief Subdivisions—The Colonial Skeleton—The Individual Moss-animal—Muscles and their Action—Respiratory, Circulatory, and Reproductive Systems—Structure and Functions of the Appendicular Organs—Classification and Anatomy of Minor Groups—Geographical and Bathymetrical Distribution of Marine and Fresh-water Genera—Geological Range—Reproduction of the Colony and of the Individual—Embryological History—Affinities and Systematic Position of the Brachiopoda and Bryozoa.

ALL the Brachiopoda,† or mantle-breathing bivalves, are exclusively inhabitants of the ocean. They are found attached to stones, rocks, corals, sponges, sea-mats, and sea-weeds, or adhering to each other in masses, in shallow water, and are dredged from considerable depths. The class—a very extensive one—comprises about one hundred and thirty genera, and between four and five thousand species. By far the greater number of these are extinct forms; but the one hundred and thirty existing species merit consideration as the surviving members of a most ancient but now declining race. For these lowly molluscs were among the first representatives of life in the ancient seas of our planet, during remote geological ages.

The first figures and descriptions of members of this group were given by Prince Fabio Colonna



Fig. 1.—*TEREBRATULA CUBENSIS* ATTACHED TO CORAL AT A DEPTH OF 420 FATHOMS, OFF ASCENSION. (After Davidson.) ("Challenger" Expedition.)

in 1606. But the animals were for many years confounded with the "plate-gilled" bivalves (Lamellibranchiata) already described (p. 230), and the great Cuvier was the first to recognise their distinctive characters. He constituted a separate class for the reception of the Brachiopoda, signifying "arm-footed," under the impression that some largely-developed internal organs which occupy the greater portion of the interior of the shell—the so-called "arms" or "feet," which are the special characteristic of these organisms—were used as feet, and employed in the processes of locomotion. It is now known that these organs, although capable of protrusion, in some genera, beyond the marginal or outer edges of the shell, are never really used for locomotion. De Blainville's subsequently proposed title of "mantle-breathers,"‡ referring to the respiratory function

exercised by the pallium or mantle—the delicate membranous internal lining of the shell—is therefore used by some naturalists. But the first name enjoys the right of priority and long habit, and as Brachiopoda these animals will probably ever be better known, although they never walk upon their so-called arms or feet.

In fact, their powers of locomotion are somewhat limited, being restricted, in most genera, to a free movement on the muscular stalk or peduncle. Members of one genus, however, jerk themselves about by the sliding action of their valves, swinging the fringes of setae, or minute bristles edging the mantle, to and fro like the oars of a galley, and leaving a peculiar track in the sand. Young individuals, in the earlier stages of growth, are quite free and unattached, swimming actively about in the water. Others were fixed during a portion of their lives, the opening for the peduncle subsequently becoming closed. A few of the fossil forms show no marks of attachment, and are believed to have always enjoyed a free existence.

The Brachiopoda were also called Lampades, or lamp-shells, by the older naturalists, the shape of the shell, and the hole serving for the passage of the peduncle, suggest-

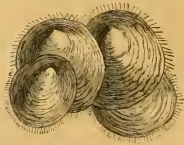


Fig. 2.—*DISCINISCUS LAMELLOSA*. OFF CALLAO, PERU. (After Davidson.)

* Greek, *brion*, moss; *zoon*, an animal.

† Greek *brachion*, an arm; *pous*, the foot.

‡ Palliobranchiata, Lat., *pallium*, a mantle; Greek, *branchia*, gills.

ing this comparison with an Etruscan lamp. It is one, however, that is applicable to comparatively few species. At one time these organisms were ranked with the higher shell-fish—after the Gastropoda—thus taking precedence of all the bivalve class. But they were not long allowed to maintain this position; first reduced to a lower grade, they were afterwards ejected from the ranks of the shell-fish proper, and relegated to an inferior division of the molluscan type to which the name of “mollusc-like animals”* was applied. Some recent authorities assign them a very different position, and after detailed observations of the successive stages of development assumed by the immature animals, place them with a section of the worm family (Annelida) that surround themselves with a tubicolar sand-covering, a habit, by the way, which is shared by one family of the Brachiopoda. But the adult animal of all the mantle-breathing bivalves is always enclosed between, and protected by, an external shell forming two valves or pieces, which are generally regarded as “front” and “back” shields, instead of right and left, as in the bivalve shells (p. 230). Each of the two pieces composing the shell is always symmetrical in itself, but the shell is never “equivalve,” as one piece is invariably larger than the other. Yet the expanded edges are nearly always level and opposable, resting one upon the other.

None of the recent Brachiopoda are very large, but many of the extinct forms attained considerable dimensions, and in one Carboniferous species (*Productus giganteus*) the shell sometimes measured over a foot in length and in breadth. The shells of many species are quite smooth, or striated and marked with circular lines of growth; others are coarsely or finely ribbed with longitudinal or transverse ridges, or depressions. Some are white and of a transparent and glassy texture, as in the deep sea forms. Those inhabiting Arctic or Northern seas are of a dull grey colour, and the shell is more robust; while the tropical species are often brilliantly coloured, the prevailing hues

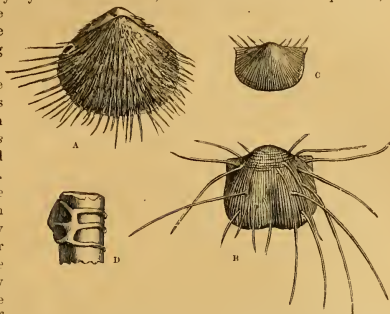


Fig. 3.—A, *RHYNCHONELLA SPINOSA*, INFERIOR OOLITE; B, *PRODUCTUS LONGISPINUS*, CARBONIFEROUS; C, *CHONETES*; D, VENTRAL VALVE OF *PRODUCTUS COMPLEXENS*, LOWER CARBONIFEROUS LIMESTONE. (After Davidson and R. Etheridge, Junior.)

being crimson, yellow, emerald green, brown, or bluish black. Traces of coloration are occasionally preserved in fossil specimens, many of which are beautifully sculptured externally, and some extinct forms were additionally ornamented with long and elegant spines, attached to the outer surface of their shells. In some genera the spines covered the whole exterior, and were coloured like the shell, as in the *Rhynchonella spinosa*† (A) of the Oolitic seas, or long and slender, were irregularly distributed over the surface of the ventral valve (B). In others they were merely developed in the region of the hinge (c). The spines, in one instance, armed with minute hooklets, were often four or five times the length of the shell. They were generally tubular, sometimes with a double chamber like a gun. (Davidson.) Opinions have varied considerably with regard to the functions of these appendages. Some writers consider them merely ornamental, others, as canals admitting the sea-water to the interior of the shell, or as organs of attachment which served as anchors to moor the animal at the bottom of the sea. A tiny species that flourished in the Carboniferous seas, though a silent witness, furnishes irrefutable evidence that they occasionally acted as clasping organs. Fig. 3, D, represents this small “embracing” *Productus*, encircling the stalk of a sea lily (crinoid), with its slender spines. Thus the animal, enabled to resist the rude buffets of the waves, was preserved from rough contact with surrounding objects.‡

The Brachiopoda are subdivided into two principal groups. All members of the first

* The Molluscoida of Milne-Edwards. † Spiny little beak. A spine-covered species of this genus (*Rh. döderleinii*) has been recently discovered living in Japanese waters. ‡ Robert Etheridge, Jun., F.G.S., *Journal of the Geological Soc.*, 1876.

and more highly organised division of *Tretenterata*,* are characterised by the presence of an anal orifice. Those belonging to the second and lower group of *Clistenterata*† are not provided with that opening, and the intestinal tube ends in a blind sac. These important distinctive characters, first made known by the anatomical researches of Messrs. Hancock and Huxley, have since been confirmed by Professor Morse in a living *Clistenterate*. He witnessed the rejection of the waste products by the mouth, the only outlet in one of the lower forms (*Terebratulina*). Other remarkable structural differences are associated with these distinguishing features. The first, or *Tretenterate* group, is devoid of any internal skeleton, the two valves of the shell being quite free, and kept in place solely by the shell muscles. In at least one genus of it (*Lingula*), they move freely from side to side, opening obliquely by means of the strong "lateral" or side muscles, specially restricted to that purpose (Fig. 6, *j k l*). Members of the second group generally have the two valves firmly united by hinge teeth, which fit into sockets in the opposite valve and effectually prevent any lateral movements. Consequently, the side muscles are not developed, but are replaced by others which enable the animal to open its shell a very little way in a horizontal direction; or, in one genus (*Thecidium*) at right angles. But the gape is exceedingly small amongst the *Brachiopoda*, as compared with that of the true bivalved mollusca. An internal skeleton, for the support of the breathing organs, is usually present in the *Clistenterata*, and the shape it assumes is most variable. As the *Tretenterates* appeared first on the globe, the second and inferior forms may be regarded as possibly their degenerated descendants. Members of one ancient and extinct family,‡ believed to be exclusively restricted to the seas of the Silurian age, present a general external resemblance to the lower and *Clistenterate* species. They appear also to have possessed some characters of both groups, rudimentary hinge teeth, indicating interlocking valves, being associated with the impressions left by side muscles which may have enabled the animal to move its shell sideways. The chemical constituents of these often massive shells are also of a different and somewhat intermediate nature, carbonate of lime entering far more largely into their structure than into that of *Lingula* and *Discina*, which are almost exclusively composed of a corneous or horny substance; while in the shells of *Crania*, *Glottidia*, and all the *Clistenterate* genera the calcareous element predominates.

The shell is secreted by the mantle, and appears (in *Terebratulina*) in the fifth stage of the development of the hitherto naked embryo. It first develops in the region of the peduncle, subsequently increasing in growth at the margins of the valves, and it differs so considerably, both in structure and mode of growth, from that of the lamellibranch, that a small fragment can be readily identified by microscopic examination, even when derived from a fossil species. Dr. Carpenter describes the shell as consisting of two layers which correspond in thickness with the outer layer only of that of the lamellibranch. It has a fibrous prismatic structure which gives it a scale-like appearance (Fig. 4, A). In many genera the shell is perforated with minute canals, differing in size and situated at variable distances from each other.

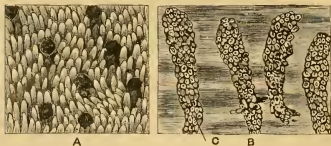


Fig. 4.—SECTIONS OF SHELL STRUCTURE. C, CECAL TUBULI OR PROJECTIONS. (After Carpenter.)

They make their appearance in the earliest stages of the development of the shell; the largest measure $\frac{1}{16}$ and the smallest $\frac{1}{320}$ of an inch in diameter. These canals are charged with cellular projections (Fig. 4, B, C) of the fleshy mantle, corresponding in position with tiny cells spread over the upper surface of this delicate membranous covering of the animal. Their functions are not absolutely determined, but Dr. Carpenter believes them to be subservient to respiration.

Of the two valves composing the shell, the front or ventral valve (Fig. 5, A) is generally the larger. In many forms it is produced at the apex (*a*) into a prominent beak perforated at its extremity by a hole, the foramen (*f*), for the passage of the peduncle or bundle of muscular fibres by means of which the animal attaches itself to neighbouring objects. The back shield, or dorsal valve (Fig. 5, B), contains the animal, and also a variously-shaped

* Greek, *tretos*, perforated.

† Greek, *cleistos*, shut; *entera*, intestines.

‡ The *Trimerellida*.

process, the loop (*l*), which forms the internal skeleton and support of the more or less developed brachial or breathing organs, "the arms." This delicate calcareous appendage—formed of the same substance as the outside shell—in reality consists of slender prolongations of the shell lip. It varies considerably in size, shape, and method of attachment to the interior of the dorsal valve, and is specially characteristic of the inferior or Clistenterate group. The valves are firmly attached to each other by two curved hinge-teeth (*A, t*), which fit into corresponding depressions or sockets in the opposite dorsal valve (*B, s*) in the articulated species. When thus secured the united valves cannot be easily detached, but they are opened readily by the action of the shell-muscles, five pairs of which are developed for that purpose (Hancock). Two pairs of adductors, *a*, close the

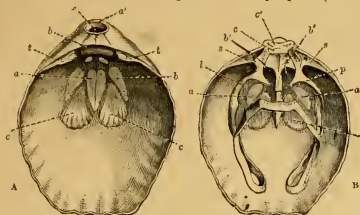


Fig. 5.—A, VENTRAL; B, DORSAL VALVE OF WALDEHEMIA AUSTRALIS, SHOWING SCARS OF MUSCULAR ATTACHMENTS. (After Davidson.)

a', apex; *f*, foramen; *p*, septum; *t*, teeth; *s*, sockets; *l*, loop; *a*, adductor; *c*, divaricator; *b*, ventral adjuster; *b'*, peduncular muscles.

(Fig. 6, *g*) opens the valves. The pair of centrals (*h*) closes them; three pairs of laterals (*j, k, l*) are restricted to the side of the valves, and slide them; while the fifth pair of transmedians (*i*) controls the movements from side to side of the beak or umbonal regions of the shell. (King.) There are no peduncular muscles. The muscles leave definite arched, crescent, or otherwise-shaped impressions on the interior of the valves at the point of their attachment to the shell. These scars, recognisable even in many fossil forms, serve as additional clues in referring a genus to one or other of the particular family groups.

The peduncle of the Tretenterates passes either through a fissure in the ventral valve, as in *Discinisca* (Fig. 2), or between the beaks of the almost equivalved shell, as in *Lingula* (Fig. 7), in which this mooring organ is sometimes enormously developed, occasionally measuring over nine inches. It is mobile, ringed,* highly contractile, and composed of an outer horny layer, and an inner one of longitudinal muscular fibres. It is hollow, and the blood, which is of a red colour, courses back and forth in the central cavity, circulating for several days after death and separation from the thoracic portion of the animal. Its surface is crowded with minute pores, and in two species (*Lingula pyramidalis*† and *L. anatina*), which live free in the sand, and do not adhere by its extremity, has the power of agglutinating a sand tube. This is promptly repaired when broken or removed from the animal, an operation thus described by Professor E. S. Morse:—"When the peduncle was broken off, a bulb of sand would soon be agglutinated to protect the broken end, and not only sand was used, but bits of seaweed; and in one case a little stick was incorporated in this structure. I brought home with me to Salem, Mass., a number of living specimens, and these were kept alive in large bowls, from

valves. Another pair, divaricators, open them, *c, c'*, and two others, the ventral adjusters *b*, and the peduncular *b'*, adjust the shell upon the peduncle.

Among the higher or Tretenterate group the muscular system is very complicated, and in the *Discinidae* (Fig. 2) approaches nearest to that of the articulated genera. In the helmet shells (*Craniadae*, Fig. 9) the valves move upon the straight side, as on a hinge without sliding, but in *Lingula*, (Fig. 7) they have been observed to slide from side to side. This genus has five pairs of muscles, and an odd one, their functions being thus apportioned:—The single muscle in the region of the beak, the umbonal

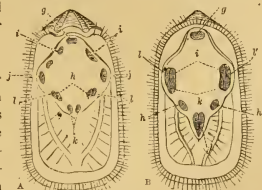


Fig. 6.—A, VENTRAL; B, DORSAL VALVE OF LINGULA ANATINA. (After King.)

g, Umbonal Muscles; *h*, Centrals; *j, k, l*, Laterals; *i*, Transmedians.

* According to researches of W. K. Brooks ("Results of the Chesapeake Laboratory, 1879"), the segmentation of the peduncle in *Lingula* described by Morse is not a permanent character.

† Now known as *Glottidia audeberti*, Broderip.

June to October, by imitating as far as possible their natural surroundings. They would often protrude above the surface of the sand, and instantly jerk back when alarmed. On emptying the sand from the bowl one day, great was my surprise to find that all of the *Lingula* had covered the bottom of the bowl with large irregular sand-tubes, cemented to the sides and bottom of the dish, the tubes running over each other, and presenting precisely the appearance as that produced by *Terabella* and allied forms when kept in dishes in this way." The peduncle is sometimes preserved in a fossil state.

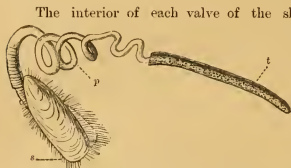


Fig. 7.—LINGULA PYRAMIDATA. (After Morse.)

p, Peduncle; t, its Terminal end encased in Sand tube; s, Setae or Bristles.

The interior of each valve of the shell is invariably lined by the pallium or mantle, a delicate membrane which closely invests the body of the animal occupant. It is divided into two lobes, which are united only at the peduncle and extend to the outer edges of the shell, where they are fringed with bristles (Fig. 7, s) of variable thickness, and length. The mantle is composed of two distinct layers: the outer adheres closely to the valves of those genera in which the shell substance is perforated by canals which are partially filled with its minute projections. The under layer, of a thinner, granulated texture, is clothed with vibratile cilia. The mantle secretes, nourishes, and repairs the shell substance, and is also concerned with the processes of respiration, the purification and circulation of the blood. It also serves in some cases as a medium for the discharge of the eggs, which apparently accumulate in the larger sinuses of its arterial system. In some genera, a series of very minute calcareous plates stiffen the mantle and form a protection over the veins, the breathing organs, and the *perivisceral cavity*—as that small portion of the shell which is occupied by the digestive organs is termed, to distinguish it from the larger space—the *pallial chamber*—filled by the mantle. This—separated from the former by a membranous wall clothed with cilia—contains only the brachial organs and mantle, and may be compared with the tentacular sheath of the Moss-animal. (See p. 273.)

The largely-developed fleshy brachial organs, so characteristic of the Brachiopoda, occupy a considerable portion of the pallial cavity of the shell. Formerly regarded as uniting the functions of respiration and locomotion, they gave the name of Brachiopoda to the group. But they are more correctly designated the brachial appendages. They are often supported by the calcified loop-shaped prolongations of the shell lip already alluded to (Fig. 5, b, l). They are now known to act as accessory breathing and circulatory organs, and are also employed in collecting and directing towards the mouth situated at their base currents of water; and in eliminating therefrom the microscopic organisms, consisting chiefly of minute plants, diatomaceæ and infusorian animalcules which constitute the nourishment of the animal inhabiting the shell. Hancock describes these organs as consisting of a flexible membranous tube, fringed on one side by a double row of hollow tentacles or cirri (Fig. 8, i). Each of these is capable of separate movement, and is in turn clothed with pliant hairs or cilia. These cilia draw the "minute nutrient particles" down into the groove or gutter which lies at the base of the tube, which is also lined with cilia, and so the nourishment is conveyed down its course to the mouth situated at the origin of the arms. This opening—a simple slit—communicates with a comparatively short gullet, which leads into a more elongated stomach. The alimentary canal, of variable length, ends somewhat abruptly in a blind sac in the lower forms. In the higher, it is prolonged, turns upwards, and terminates in an anal orifice (g) between the right edges of the mantle nearest the dorsal valve.

The liver (Fig. 8, r)—of a greenish colour and very large—is divided into two lobes, respectively situated on each side of the alimentary canal. It communicates by two or three short ducts with the stomach, and in the higher forms is flanked by the large-sized genital organs of both sexes. Among the Clisterates the generative products—developed and set free in the perivisceral cavity—are conveyed through trumpet-shaped and ciliated ducts into the pallial chamber, thence gaining access to the sea-water. The pallial blood-channels lie between the two layers composing the mantle. A series of canals running one into the other, and presumed to be vascular, permeate the membranous

lining of the perivisceral space, as well as the investing ovarian membranes, but the details of the very rudimentary circulatory system of the Brachiozoa are imperfectly known. Some of the Brachiozoa were formerly credited with the possession of two or even four pulsating organs. But the so-called "hearts" of Cuvier and Owen are now known to be connected with the oviducts; while the "pyriform vesicle" of Hancock and Huxley has proved to be non-contractile, without muscular walls, and to have no connection with the arterial system. Semper has demonstrated the non-existence of a heart in *Lingula*, and Morse has more recently maintained that the circulation of the blood is entirely due to "ciliary action." Thus the presence of the plant, hair-like cilia, so often referred to as present on the mantle, the lining of the body cavity, the cirri of the arms, and in the tube at their base, acquires additional significance, for by their exclusive agency the blood is distributed through the complicated vascular system; while the function of aëration, generally effected by the gills—the equivalents of the lungs of other animals—is among these lowly molluscs, divided between the mantle and the "arms," a fact that illustrates the imperfections of the Brachiozoal organisation, and their lowly rank in the molluscan type.

The nervous system is composed of two nerve-centres, united by a nerve, forming a collar round the gullet, and communicating by a series of minute fibres with the arms, the mantle, and pseudo hearts—the oviducts. Being headless, or acephalous, the Brachiozoa have no brain. But Professor Morse has detected the presence of a rudimentary organ of hearing in *Lingula*. Eye-spots are developed in all the embryos, but disappear in the later stages of growth. Yet the adult animals are sensitive to light; and although possessing neither well-developed foot, head, eyes, heart, nor one localised breathing organ, exhibit a certain amount of activity and intelligence in fulfilling all the necessary purposes of their existence. The following description has been given by Professor Morse of the mode of life of a youthful individual of the genus *Terebratulina*:—"The animal whirled quickly on its peduncle. When at rest the valves were always closed, and rested on the rock. From this position it turned slowly more than half-way round, raising the body at the same time almost erect. This movement being completed, the valves would very slowly open, and the cirri expand as if to perform a grasping motion; in no case, however, were they projected beyond the margins of the valves. The cilia lining the cirri produced gentle currents in the water. In this position, with the valves widely open and cirri expanded, the animal would remain motionless for twenty or thirty seconds, and then, with an abrupt closing of the valves, suddenly assume its first position. In watching these motions for a long time, one could not help being impressed with the fact that caution was evidently indicated in the slow and careful movements made in elevating and opening the shell; while the prompt closing of the valves, and the alert manner in which the animal regained its first position, seemed to show that food had been secured, and further caution was unnecessary."

Nearly all the Brachiozoa can be referred to one or other of the two great groups into which the class has with common consent been divided, a separation based upon the important structural differences already detailed, which are epitomised in the names *Tretenterata* and *Olistenterata* respectively, applied by Prof. William King. The primary groups are again subdivided into eleven families or assemblages of allied forms, each of which may contain either one or several genera and sub-genera. In accordance with the system elaborated by Mr. Thomas Davidson, in his numerous memoirs on British and Foreign Fossil Brachiozoa, these minor classificatory relationships are connected with the chief structural peculiarities of the animal—the fleshy breathing organs—their nature and shape differing considerably in those forms in which the internal skeleton is absent, or only slightly developed, and depending upon its variable modifications when present. The supporting

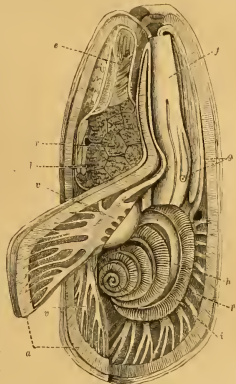


FIG. 8.—ANIMAL OF *LINGULA ANATINA*. ENLARGED. (After Hancock.)

a, Dorsal Lobe of Mantle; v, Vascular System; b, Brachial Organs; c, Cirri; d, Perivisceral Cavity; e, Pallial Chamber; f, Intestine; g, Anus; h, Lateral Muscles.

calcareous labial appendages (Figs. 5, B, *l*) are therefore one of the most important features affecting the life and organisation of the animal inhabiting the shell, and their value as classificatory agents is apparent. Frequently preserved in a fossil state, there can be no doubt that they afford the simplest and readiest mode of determining the true relationship of one adult form of Brachiopod to another, and one that is infinitely preferable to the purely external characters of these very variable shells. In the subjoined table of families, typical genera are placed first, and those represented solely by extinct forms are printed in italics :—

	Family.	Genera.
ORDER TRETENTERATA	LINGULIDÆ	Lingula, Glottidia, <i>Lingulops</i> , <i>Obolus</i> .
	DISCINIDÆ	Discina, Discinisca, <i>Trematis</i> , <i>Siphonotreta</i> .
	CRANIADÆ	Crania, <i>Craniops</i> , <i>Craniusens</i> .
	<i>Trimerellidæ</i>	<i>Trimerella</i> , <i>Monomorella</i> , <i>Dinobolus</i> .
" CLISTENTERATA	<i>Productidæ</i>	<i>Productus</i> , <i>Chonetes</i> , <i>Strophalosia</i> .
	<i>Strophomenidæ</i>	<i>Strophomena</i> , <i>Orthis</i> , <i>Leptæna</i> .
	<i>Pentameridæ</i>	<i>Pentamerus</i> , <i>Stricklandina</i> .
	<i>Spiriferidæ</i>	<i>Spirifer</i> , <i>Spiriferina</i> , <i>Meristella</i> , <i>Athyris</i> .
	RHYNCHONELLIDÆ	<i>Rhynchonella</i> , <i>Rhynchopora</i> , <i>Atrypa</i> .
	TEREBRATULIDÆ	<i>Terebratula</i> , <i>Waldheimia</i> , <i>Argiope</i> , <i>Laqueus</i> , <i>Kingena</i> .
	THECIDIDÆ	Thecidium.

ORDER TRETENTERATA.

FAMILY, THE LINGULIDÆ.*

The typical genus *Lingula*, one of the most ancient and persistent of Brachiopoda, is, as might be expected, a very hardy animal. The hingeless valves of the usually green or dusky brown shells are nearly equal in size, and it is from their elongated or tongue-like shape that the family name is derived (Fig. 7). The thick fleshy breathing organs with inwardly-directed spires are unsupported by any elaborate calcified process, but merely strengthened by a simple longitudinal plate or septum, rising from the centre of the dorsal valve. Professor Morse describes the American and Japanese species as living free and partially buried in sand, and further states that "the anterior borders of the mantle contract in such a way as to leave three large oval openings, one in the centre and one on each side. The bristles, which are quite long in this region of the animal, so arrange themselves as to continue these openings into funnels, and entangle the mucus escaping from the animal. A continual current is seen passing down the side funnel and escaping by the central one." They bury themselves quickly in the sand, and the lengthy and worm-like peduncle agglutinates a sand-tube.

THE DISCINIDÆ.

This venerable family is represented by the long-lived genus *Discina* in the existing oceans. The two horny unarticulated valves are circular or disc-like, hence the name. The upper, resembling that of a limpet, is smooth with an almost central apex. The lower is perforated for the passage of the short plug, or byssus, by means of which they adhere to each other. No external skeleton is developed for the support of the breathing organs, which curve backwards, and end in small spires directed downwards. Very little is known of the habits of the living species which, widely distributed, exist both in shallow water and at very considerable depths.

THE HELMET-SHELLS.

The Craniadæ† attach themselves by the flat or under valve to other bodies. The helmet-shaped appearance of the upper valve gives the name to the group. On the interior of the thick and hingeless calcareous shell four distinct muscular impressions are visible. The arms (Fig. 9, *b*) are free, coiled in spirals towards the concave space of the dorsal valve, which is generally firmly attached to foreign objects. The two valves are only united by muscles, and separate readily on the death of the animal, hence the large number of single valves occurring in a fossil state. They range in time upwards from the Silurian epoch.

* Latin, *lingula*, a little tongue.

† Greek, *kranos*, a helmet.

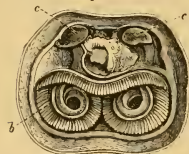
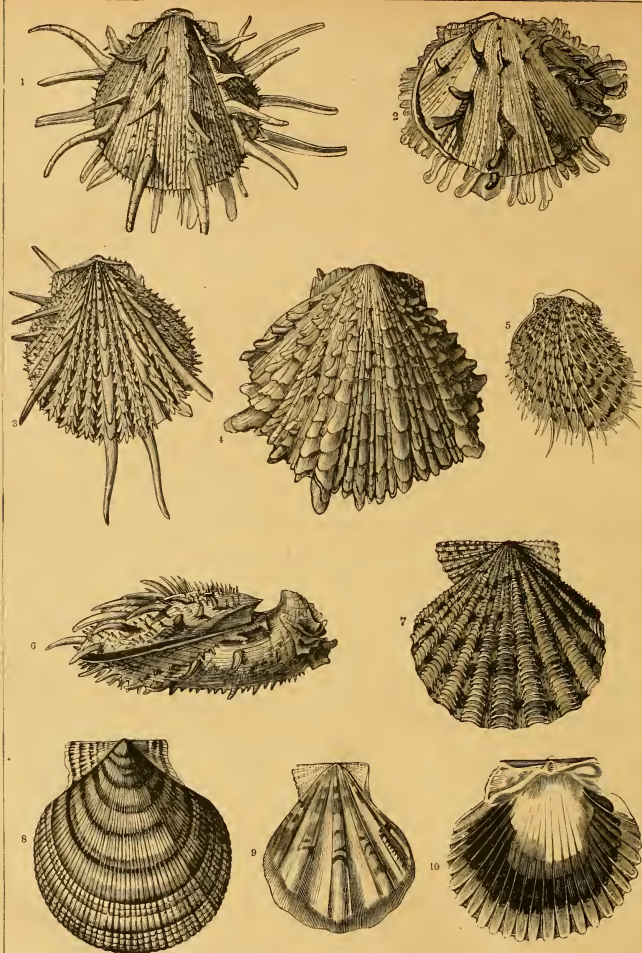


Fig. 9.—CRANIA ANOMALA.
(After Davidson.)

a, Brachial Organs; *c*, Two Muscular Impressions.



SHELLS OF PECTEN AND SPONDYLUS.

1, *Spondylus regius*; 2, *S. gæderopus*; 3, *S. imperialis*; 4, *S. crassiquama*; 5, *S. rullians*; 6, *S. avicularis*; 7, *Pecten pallium*;
8, *P. islandicus*; 9, *P. plica*; 10, *P. purpuratus*.

THE TRIMERELLIDÆ.

The four genera comprised in this family, all apparently restricted to the Silurian seas, occur abundantly in rocks of that age in Sweden, Russia, and Canada. The shell, generally calcareous and often extremely massive, was characterised by a raised and vaulted platform for the attachment of the muscles. The animal was probably Tretentate, as no support for the brachial organs is preserved. But the occasional presence of rudimentary hinge-teeth and characters of the muscular system indicate that the structure of these extinct forms was somewhat intermediate between that of the Tretentate and Clistentate group.

ORDER CLISTENTERATA.

FAMILY, THE PRODUCTIDÆ.*

This family ranges in time from the Silurian to the Permian epoch. It includes a number of fossil forms, which vary considerably among themselves. The prominence of the beak and shoulder of the shell suggests the generic name of the type (Fig. 3, B, c). The shell substance was perforated by canals, and the exterior of the ventral valve was often profusely ornamented with tubular spines, sometimes restricted to the hinge region. The brachial organs, contained in a depression of the dorsal valve, were not supported by any internal skeleton. In some genera the two valves were united solely by muscles; in others hinge-teeth and sockets were developed. The distinct impressions of the adductor muscles are very characteristic of this family.

Members of the large family of the Strophomenidæ appeared in the Cambrian seas, and became extinct in the Upper Liassic period. The valves of these compressed shells were usually concavo-convex, and furrowed from hinge to margin. Hinge-teeth were present, and the breathing organs were supported by a short process. The figure of the genus *Orthis* (10, A), showing the impressions of the mantle, vascular and muscular systems, illustrates the manner in which the anatomy even of fossil species can be determined. In the Pentameridæ† (Fig. 10, B), or five-chambered shells, the articulated valves were divided into five parts or chambers. Those at the side were occupied by the arms and ovaries, and the V-shaped division near the beak by the digestive organs. The shell is smooth and imperforate, with a prominent beak. This family was represented only in the Silurian, Devonian, and Carboniferous epochs.

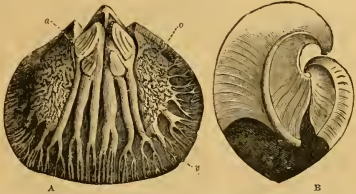


Fig. 10.—A, INTERNAL CAST OF DORSAL VALVE OF *ORTHIS*. B, SECTION OF *PENTAMERUS*, SHOWING CHAMBERS. (After Davidson.)

A, Adductor Muscles; v, Veins; o, Ovarian Spaces.

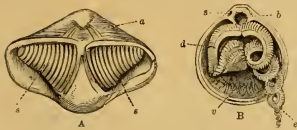


Fig. 11.—A, DORSAL VALVE OF *SPIRIFER GLABRA*, CARBONIFEROUS. B, DORSAL VALVE OF *RHYNCHONELLA PSITTACULA*. (After Davidson and Owen.)

A: g, Hinge Area; a, Spiral Labial Appendages. B: d, Arms in Natural Position; u, Unrolled; b, Dental Plates; s, Sockets; v, Vascular System of Mantle.

The Spiriferidæ appeared in the Silurian seas, and became extinct in the middle of the Liassic period. Among the family of "Little Beaks," or Rhynchonellidæ, the valves are strongly articulated, and the generally imperforate shell is three-cornered, with a small-pointed beak (Fig. 11, B). The fleshy, spirally-rolled breathing organs are merely supported by a short calcareous process, and are therefore capable of extension beyond the margins of the shell. Professor Morse witnessed this operation, and states that the appendages can be unrolled and

THE SPIRE-BEARERS.

The name of this family, which comprises some of the most beautiful of the numerous fossil forms of the class, is derived from the spiral shape assumed by the calcareous labial appendages which nearly fill the interior of the dorsal valve (Fig. 11, A). The shells are ovate, elongated, and sometimes extended into wing-like expansions. The Spiriferidæ appeared in the Silurian seas, and became extinct in the middle of the Liassic period. Among the family of "Little Beaks," or Rhynchonellidæ, the valves are strongly articulated, and the generally imperforate shell is three-cornered, with a small-pointed beak (Fig. 11, B). The fleshy, spirally-rolled breathing organs are merely supported by a short calcareous process, and are therefore capable of extension beyond the margins of the shell. Professor Morse witnessed this operation, and states that the appendages can be unrolled and

* Latin, *producta*, produced.

† Greek, *pente*, five; *meros*, part.

protruded nearly twice the length of the shell. They often remained extended a short distance for hours. Their movements were very sluggish, but the cirri were constantly in motion, and the shells sometimes closed upon the arms before they were retracted. This family was represented in Silurian times, by the type and other forms, in some of which the spires were coiled round and round like a watch spring. The Rhynchonellidae culminated in the Jurassic seas; six species only survive. Of the allied genus *Atretia*, one Atlantic species is known, and a second was recently dredged by Mr. John Brazier in Australian waters.

THE TEREBRATULIDÆ.*

This, a most extensive family, comprises a great number of generic and sub-generic forms, which are usually characterised by the large-sized perforation in the ventral or pedicle valve, for the passage of the peduncular organ of attachment. The calcified support for the respiratory and alimentary organs

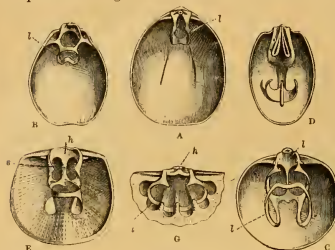


Fig. 12. — A, LOOP OF LIOTHYRIS; B, TEREBRATULINA; C, TEREBRATELLA; D, ROUCHARDIA; E, MEGERCIA; G, ARGIOPE. (After Davidson.) h, Hinge; l, Loop; s, Septum.

exhibits considerable modifications, which serve to distinguish one genus from another. Sometimes the loop is short and simple (Fig. 12, A); in the form of a ring (B); or it is long and doubled back on itself, as in Fig. 5, B, l; attached twice (Fig. 12, C) or three times (E) to the ridge or septum running down the centre of the valve. Again, the respiratory and food-securing organs may be supported by an anchor-shaped process (D), or by short ridges developed along the margins of the valves (G). It seems probable that the ringed type of loop is a further modification of the simplest and highest type—that of Terebratula. For the embryological researches of Friele have revealed the fact that in other genera the loop passes from a complicated to a simple type, assuming at successive stages shapes which are

absolutely identical with the characters of those of full-grown individuals of other genera. This discovery, however suggestive as throwing light on the genetic descent and relationship of the Brachiopoda, does not affect the value of the calcified loop for classificatory purposes, as each genus is distinctly characterised by its special form of loop in adult animals. The Terebratulidæ include the majority of existing species of the class. It was represented in the Silurian seas, and steadily increased in numbers until the dawn of the Tertiary epoch, since when its specific representatives have been somewhat reduced.

THE THECIDIDÆ.

The genus *Thecidium* is the only member of a family which apparently came on the scene of life in the Triassic age. Living species attached by their ventral valve to corals, moss-animals, and dead shells of their race, abound in the Mediterranean sea, where they were dredged in great numbers by M. Lacaze-Duthiers, who kept them alive for several weeks, and gives the following account of their habits. The animals are certainly sensible to light, for the valves were abruptly closed on the interposition of any shadow. They were generally opened very slightly; the upper moved at right angles on the hinge line, and shut with the rapidity of lightning when the animal was disturbed. The ciliated folded breathing organs, supported by a calcareous loop, are sunk in hollows in the attached valve. The shell is small, thick, strongly articulated, and its substance perforated by canals.

The Brachiopoda apparently prefer rocky shores to muddy bottoms; they are much localised and generally occur in great abundance in their favourite haunts. Out of the one hundred and thirty known genera, only twenty-two are represented by living forms. Many of these survivors have a wide geographical range, and occur at most varied degrees of depth. Ten species are found off the British coasts. The Lingulidæ, as a family, exist in very shallow water living half-



Fig. 13. — THECIDIUM MEDITERRANEUM, AS IN LIFE. (After Lacaze-Duthiers.)

* Lat'n, *terebatus*, perforated.

buried in sand shoals or mud banks, and are occasionally left dry by the receding tide. They are very abundant in certain localities, in from 7 to 60 fathoms in the tropics, the China and Japan seas, and off the Australian and Pacific coasts. They are also plentiful at low water in the Philippine Islands. Glottidia abounds on both coasts of North America. No member of this family inhabits deep water. The "Helmet Shells" (Craniadæ) exist in from 3 to 800 fathoms off the shores of Britain, Japan, and Australia. The "Disc Shells" (Discinidæ) are generally dredged in from 3 to 50 fathoms off Japan and the South Pacific coasts. They range from Baffin's Bay to south of the Cape de Verde Islands: from the Arctic regions to the equatorial Atlantic. One interesting little species of this family has succeeded in adapting itself to life in the abysses of the ocean, and enjoys a bathymetrical range of from 690 to 2,425 fathoms. It was dredged at this depth at several stations by H.M.S. *Challenger*, from its home at the bottom of the Atlantic, whence its specific name of *Atlantica* is derived. This species, however, also occurs off Australia, for, like all abyssal forms, it enjoys a wide geographical distribution. It is the only member of the more highly organised group (Tretenterata) which can really be considered an inhabitant of the deep seas.

The species of the order Clisterata are more frequently found in deep waters, although some, like the Australian *Waldheimia*, are merely washed by the tide and may be gathered by the hand, "like limpets on the shore." A species of the genus *Kraussina* is also left dry by the tide on that desolate rock of St. Paul's Island in mid-Atlantic. The family of "little beaks" is represented in the New Zealand area, off Japan, in the Arctic and North and South Atlantic Oceans, at depths varying from 10 to 690 fathoms. *Thecidium* (Fig. 13) inhabits the Mediterranean Sea, and may also be sought off Jamaica and the Mauritius in from 30 to 300 fathoms. But it is among the universally-distributed Terebratulidæ that the greatest variety of depths has been recorded: from 200 to 600 fathoms being the usual limit of the majority of species. Five, however, are known to live at from 1,000 to 1,500 fathoms; four in from 1,500 to 2,000, and three in from 2,000 to 2,900 fathoms. The *Challenger* dredged a very pretty little species of Terebratula at the last-mentioned depth (Fig. 14). Its occurrence off Valparaiso in 2,160 fathoms, and South Australia in 2,600 fathoms, affords another illustration of the fact that the deep-sea Brachiopoda are uniformly and widely diffused. The same species always recur at stations far distant from each other, a fact that is probably owing to the uniformity of the temperature, which below a certain bathymetrical limit never exceeds a few degrees above freezing-point. It is also very remarkable that the shells of the deep-sea forms are invariably delicate, and so transparent that the muscular impressions and the shape of the loop can often be distinguished from the exterior. Yet, notwithstanding the exceeding delicacy and fragility of their shells, the animals sustained life at a depth where the pressure of the water exceeded two tons and a half to every square inch of surface.



Fig. 14.—*TEREBRATULA WYVILLII*. 2,900 fathoms. (After Davidson.)

Thus it is evident that these shell-fish can adapt themselves to life under the most varying conditions of temperature and depth, whether in Arctic or Tropical regions, at low-water mark, or in the untroubled abysses of the ocean. Nor is their range in time less extended than their bathymetrical limits or present geographical distribution, for the Brachiopoda were among the first representatives of life in the primeval oceans.

Truly of most ancient lineage, they are found in the lower Cambrian strata, and formed a very important feature of the animal community in the following "ancient life" epoch, often called the "reign of molluscs" from the numerical preponderance of those organisms. Members of the Tretenterate group were, according to our present knowledge, the first to make their appearance in the Cambrian seas, where the remains of the earliest known species, a Linguloid form (*Lingulella primeva*), were embedded. Only two genera, *Lingula* and *Discina* (Figs. 7 and 2.), out of about 130, have persisted throughout all the geological ages up to the present day. *Crania*, *Rhynchonella*, *Terebratula*, *Waldheimia*,* and *Glottidia*, a sub-genus of *Lingula*, date from the Silurian. But the majority of the remaining 124 generic forms enjoyed a comparatively brief existence, appearing in one era to vanish at or before its close. Thus, three

* The genus, previously only known from the Jurassic upwards, was discovered by Mr. Davidson in strata of Upper Silurian age.

only are special to the Cambrian, twenty-nine to the Silurian, fourteen to the Devonian, nine to the Carboniferous, while four are especially characteristic of the Permian strata which terminate the Palæozoic, or ancient life epoch, during which about 3,000 species existed. Some of these occur only in certain localities, but many had as wide a geographical range in the past as some representatives of the class in existing oceans. A species of the "spire-bearing" family, for instance (*Spirifer lineatus*), is found in the Carboniferous rocks of North and South Europe, Asia, America, and Australia. When the Silurian rocks were deposited, the Brachiopoda far exceeded their bivalved contemporaries in number, but to-day the conditions are quite reversed, and the Lamellibranchiata outnumber them in the ratio of forty-four to one. During the Mesozoic ages, the Brachiopoda declined in numbers, and in the more recent Tertiary epoch their ranks became sadly thinned. In the existing oceans they can be numbered only by tens instead of by thousands, for but an insignificant remnant of 130 species now survives. They abound in all marine deposits, and are most valuable guides in determining the relative ages of all the stratified rocks.

The sexes are distinct in these bivalves, which are always reproduced by means of fertilised ova, and never by the process of budding or gemmation. The eggs are white, kidney-shaped,

and irregular, and are discharged in the form of a white powder between the margins of the mantle, and hang in clusters from its terminal fringe of bristles. They are deposited from April to September, and the animals attain their full growth in a single season, and some, it is believed, live but a year. The embryo, soon after its development from a circular cellular mass, becomes subdivided into two, three, or four lobes or segments of unequal size (Fig. 15, A). They are contractile, and swim freely by means of the movable cilia with which they are covered. Eye-spots and long tactile bristles are developed. Subsequently the embryo attaches itself by the hinder segment, which forms the head of the animal, the internal organs make their appearance, are succeeded by the mantle, and the rudiments of the shell plates, which distinguish the adult animal. The embryos of existing representatives of the earliest known hingeless forms, *Lingula* and *Discina*, are so closely allied as to be almost indistinguishable. The shape of the shell, and the length of the peduncle in some members of the later-appearing family of Terebratulids, in some stages presents a remarkable resemblance to *Lingula*, while, at a more advanced stage of growth, the extreme prolongation of the beak, or rostral portion, recalls the corresponding structure in the complex and widely distributed Silurian Trimerellidæ. At another stage, the hinge area resembles that of the *Spirifere*, and the young Terebratulina assumes the position those genera must have adopted.

Morse thus describes the actions of a young Terebratulina.

"The cirri of the arms moved frequently and in various directions, though generally performing a grasping motion, as if securing some bit of food, imitating precisely the movements of the cirri in the Bryozoa; and this resemblance was the more complete from the fact that the tentacles were densely clothed with cilia, and their movements caused visible currents in the water." In a more advanced stage, the cirri (fringes) stand erect upon the arms, and vividly recall the horseshoe-shaped forms among the Bryozoa. In fact, the alliance between the Mantle-breathing bivalves and the Moss-animals is a very close one, although at a first sight it must be admitted that no two animal types could apparently be more dissimilar.

The facts concerning the life history, distribution, and classification of the Brachiopoda, here briefly epitomised, have been mainly derived from Davidson's well-known contributions to the "Memoirs of the Palæontographical Society," the "Geological Magazine," and the "Results of the

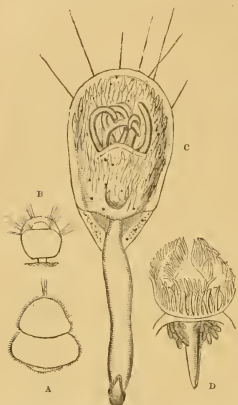


Fig. 15.—A, FREE-SWIMMING CILIATED LARVA OF TEREBRATULINA; B, ATTACHED; C, LATER STAGE; D, HORSE-SHOE STAGE OF LOOP. (After E. S. Morse).

"Challenger Expedition" (Zoology, Vol. I.). For anatomical structure, the works of Hancock, Owen, Huxley, King, and others have been consulted; while for the habits of the animals, embryological history, and systematic position of the class, Morse's various memoirs (Boston Society of Natural History) have been largely quoted. To Mr. T. Davidson, F.R.S., and Professor E. S. Morse my acknowledgments are due for further information kindly afforded.

THE BRYOZOA, OR MOSS-ANIMALS.

This group includes a number of usually compound organisms, often of small size, and presenting remarkable varieties of form, epitomised in the English names of sea-mosses, sea-mats, sea-scurfs, and lace-corals, which are applied to the most familiar examples of the class. Some are erect, like, seaweeds, leafy, branching, and plant-like in their mode of growth; others resemble fungi, sponges (Fig. 19, A), or simulate the delicate net and lace-work of the Coral. The creeping, sub-erect, and encrusting species form a distinct type, and adhere to submerged rocks, shells, and stones, grow semi-parasitically on crabs, worms, or infest seaweeds, and even members of their own race (Fig. 19, B). "Some," writes Mr. Busk, "soft and flexible, composed wholly or in part of a horny substance, form delicate growths which yield gracefully to every motion of the waves, whilst others, firm, rigid, and unyielding as the rocks they live upon, bid defiance to the ravages of time and tempest."

All the Moss-animals live in water, and the greater number of species inhabit the ocean at depths ranging from between tide-marks to two hundred fathoms. Some parts of the sea-bed are covered with masses of their dead and living forms, and the blanched skeletons of the commoner species, many of which might be mistaken for seaweeds, are among the most frequent objects cast up by the retiring waves on to the shore. During life they are often very beautiful, the hard parts and associated structures being transparently white, reddish-brown, and occasionally of a purple, blue, or green colour. A few genera exhibit phosphorescent characters, and one (*Flustra foliacea*) has an odour of a somewhat indeterminable nature. Nearly all occur in the form of associated growths or colonies attached to foreign objects; members of one family (*Selenariidae*), however, are free when adult, and move by means of the largely-developed projecting organs on the external surface of the colony, after the fashion of some Sea-urchins. A single genus (*Loxosoma*) lives a solitary, independent existence, attached by a foot-gland to living organisms, the buds to which it gives rise becoming detached from the parent stem. In all cases the colony is founded by a free-swimming embryo, which on fixation gives rise to a secondary bud, whence others rapidly develop, and thus the colony is formed by a continuous process of budding or gemmation. Some parasitic species slightly alter the surface of the shell they grow upon, eating away its outer surface, and reducing the shell whose shape they assume to extreme tenuity. Several members of the "lip-mouthed" sub-order (Cheilostomata) pierce their cellular habitations, probably by some chemical agency within the substance of the shell they infest. This perforating group, represented by living forms in the Mediterranean Sea and Atlantic Ocean, is known to have existed in Tertiary and Secondary epochs, and by some it is inferred, during the "ancient life" period also.

But the Moss-animals are not entirely confined to the ocean. A number of no less interesting forms have become adapted for life in the fresh waters of the land. Among these, a genus distinguished alike for the beauty and numerical abundance of its tentacular breathing organs, whence, indeed, its generic name of *Cristatella** (Fig. 17) is derived, is specially remarkable as the most truly active member of its class. It is, in fact, the representative among the Bryozoa of the wandering genus *Lingula* of the Brachiopoda, and dwelling in lakes and ponds, creeps slowly



Fig. 16.—BUGULA PURPUROTINCTA. NATURAL SIZE.
(After Hincks.)

* Latin, *crista*, a crest.

on the flattened under surface of the colony, which forms an oval and contractile disc over the upper side of submerged stones.

The colonies, or Polyzoaria, vary in size from scarcely perceptible objects to branched or riband-like masses, in some cases several feet in length or in breadth. A moderate-sized one has been estimated to contain within an area of three square inches a population of forty thousand little animals (Gosse), and some of the larger growths comprise within their limits accommodation for two million individual occupants. But these were not necessarily all living at one time. The colony increases at the margins as fresh animals spring by budding all around, and although some of the inner and the older cells may for a while be unoccupied by active living tenants, the colony still grows; while, when one generation dies out, a second almost mysteriously supplies its place, and the once empty cells are peopled with fresh occupants. For the method both of individual and colonial reproduction is as varied among this diverse group of animals as the nature and mode of growth of the colonial external skeleton or the habits and structure of the individual, which all in turn present so many divergent features as render it difficult to give a generalised account of their structure and ways of life.



Fig. 17. —
CRISTATELLA
MUCEDO. NAT-
URAL SIZE.
(After Al'baan.)

Like the Corals, with which they were for so long confounded under the common name of "Polypi," the Moss-animals, and with far more apparent reason, were formerly regarded as vegetable organisms. Even Linnaeus, although in the end admitting the wholly animal nature of the stony Corals, was never absolutely convinced that the horny and flexible forms—such as the wreath-like Corallines (*Sertularia*), and other widely-differing animal types with which the Bryozoa were then invariably associated, on the grounds of their common possession of an external horny or calcareous skeleton—were not really members of the vegetable world. Long after, when naturalists began to base their systems of classification more on the anatomical structure of animals than on outward form, it became evident that the group of Corals, as then constituted, included animals of very different types of structure. In 1827, Dr. Grant described the animal-inhabitant of the Sea-mats, or *Flustra* (Saxon, *flustrian*, to weave), as differing much from that of the wreath-corallines; and in the following year M. Milne-Edwards arrived at the same conclusion. Meanwhile Dr. J. V. Thompson, of Cork, had long been studying the marine productions of the Irish coast, and in 1830 he published the results of his investigations on several species of plant-like animals allied to *Flustra*. This type of animal he designated a Polyzoan, a name which at once distinguished it from the Corals. Soon after, the eminent German microscopist, Ehrenberg, separated the Corals into two groups, and defined several families of his class Bryozoa, in which he included, among others, the animal type previously called Polyzoa by Thompson. The question as to which name should be retained for the class, long a matter of debate, is still a subject of controversy. That of Thompson, undoubtedly the earlier, is adopted by many British and American writers on the recent species; while that of Ehrenberg, certainly most distinctive of the class as a whole, has always been employed by Continental authors, and is universally applied to the numerous fossil representatives of the class.

The Moss-animals were next entirely withdrawn from the confines of the stony corals and radiated animals; their molluscan characters were fully recognised, and they were ranked by M. Milne-Edwards with the Lamp-shells and Sea-squirts, as an inferior order of shell-fish, under the name of the Molluscoida, or mollusc-like animals. With the Lamp-shells they still continue to be placed, although at first sight these colonies of minute animals, protected by a common external structure, present no obvious resemblance to or affinity with the individual Brachiopod enclosed between and protected by its two-valved shell. Yet, in spite of this apparent dissimilarity, the animal inhabitant of each bryozoan cell possesses many anatomical points in common with that of the Lamp-shells, so as to fully justify their joint association.

The Bryozoa have been subdivided by Nitzsche into two principal sections, the Ectoprocta* and the Endoprocta, characterised by differences in the position of the anal orifice of the alimentary tube. In the more numerous Ectoprocta, the vent (anus) is situated *outside* the circle of the tentacles surrounding the mouth (Fig. 18, B, c, a). In the Endoprocta, it occurs close to the mouth or oral

* Greek, *ektos*, outside: *endon*, within; *procta*, vent.

opening, and is therefore *within* the disc or stage from which those breathing organs originate. Both groups having the breathing organs or tentacles in a continuous series, are comprised in the Holo-branchiata.* A third and somewhat abnormal form, *Rhabdopleura* (Fig. 18, A), having a divided or winged base for the tentacles—which from their mobility and position present a close resemblance to the brachial organs of the Brachiopod—at present constitutes the section Pterobranchiata.

The Moss-animals, whether in the form of a minute shrub sprung from a creeping root-thread (Fig. 16), or occurring in branched and riband-like encrusting masses, almost invariably consist of a colony of individuals protected by a common external skeleton or cœcium,† which forms a defensive covering like the shell of a mollusc, differing, however, from that structure, inasmuch as once formed it seems to have no further connection with the animal that originally secreted it, surviving its death, and increasing independently. The assemblage of cells forming the colony or polyzoarium is composed of no less than six distinct elements, all in reality of a truly cellular nature, and present in the higher forms of the class. (F. A. Smitt.) First comes the true animal cell, the zoecium, which lodges a perfect Moss-animal. Two other kinds, devoid of inhabitants, have become metamorphosed into purely defensive organs; while some, the ovicells, are restricted to reproductive purposes. The stem-cells are simply elongated animal chambers; and lastly, the radical-cells, or root-fibres, which, sometimes hooked, act like little grapnels, mooring the colony to the soft organisms to which it is attached, or, directed upwards, terminate in free, tendrill-like claspers, enabling the clinging animal parasite to gain a firmer foothold in the branches of the organism it infests.

The animal cell is composed of two distinct integuments. The outer, or ectocyst,‡—a product of the inner or endocyst—forms the external cell wall, and is either entirely of a fleshy, gelatinous, membranous, or of a membrano-gelatinous nature. In many cases it is partially encrusted with an earthy, horny, or calcareous substance. The inner cellular membranous layer or endocyst lines the outer wall. It always remains soft, transparent, is contractile, and corresponds with the mantle of the mollusc, and forms the body-wall of the animal. In the fresh-water genera its inner surface is clothed with vibratile cilia. The endocyst terminates in a fold near the horny ring or lophophore (Fig. 18, I), from which the tentacles (t) surrounding the mouth originate. Usually credited with the functions of the enlargement of the colony, it is now also associated with the production of a third element—a tissue, the true nature of which has only recently been determined, as one highly important to the general welfare of the community. The colony is in all cases derived from the metamorphosis on fixation of a single free-swimming larva, which develops into the primary Moss-animal, whence the colonial aggregation subsequently arises by a varied process of indefinite repetition.

Each of the animal cells forms the home of a minute, but separate, animal, often termed the polypide, which, in the majority of species, possesses all the organs requisite for the exercise of its individual, nutritive, and reproductive functions. It lives an independent existence in the cell or chamber it inhabits, to the inner wall of which it is usually attached by muscles, which enable its alimentary organs to partially protrude from, and retire within, its cell at its own pleasure. This

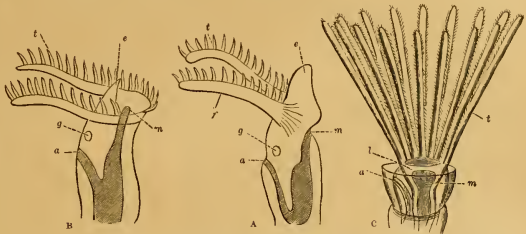


FIG. 18.—A, WINGED; B, CRESCENTIC; C, CIRCULAR TYPE OF GILL TENTACLES, ENLARGED.
(After Hancock and Ray Lankester.)

l, Lophophore; t, Tentacles; m, Mouth; a, Anus; g, Nerve ganglion; e, Epitome or foot; f, Divided or Winged base of *Rhabdopleura*.

* Greek, *holos*, entire; *branchia*, gill.

† Greek, *koinos*, common; *oikos*, house.

‡ Greek, *kustia*, a sac or bladder.

protrusion takes place at the upper part of the cell, which generally remains soft and flexible, and can often be drawn in, forming a sheath for the tentacles when the alimentary portion of the animal is retracted within the lower and harder portions of the true cell, and can be again everted on their re-appearance. The so-called orifice of the cell (Fig. 20, *or*) is in some instances protected by a row of spines—a tactile horny sheath crowned with bristles—and in others effectually closed by a movable lip or shutter controlled by muscles specially developed for the purpose (Fig. 24, *A*).

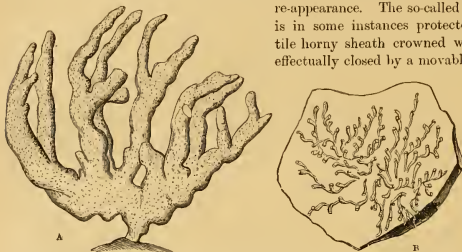


Fig. 19.—A, *ALCYONIDIUM GELATINOSUM*. (After Van Beneden.) NATURAL SIZE; COAST OF BELGIUM. B, *PLUMATELLA ALLMANI*. BRONLEY LOUGH, NORTHUMBERLAND. (Enlarged, after Hancock.)

processes, or a fine calcareous network, which acts as a sieve, and guards against the introduction into the interior of the cell of foreign substances, which might prove injurious or inconvenient to the occupant thereof. (Hincks.) Portions of the intervening outer cell-walls are occasionally of thinner structure, and contain minute perforations, through which the soft contents of the various cells are conveyed. These “communication plates” permit of that slow interchange of vital fluid which, with the exception of the association in a common lodgment, is the sole connection now believed to exist between the different members of the same colony.

Within this double-walled sac, or animal cell, the alimentary organs of the Moss-animal are suspended in the perivisceral cavity (Fig. 20, *d*), and float freely in a colourless fluid, consisting partly of water admitted from the exterior, and products of digestion which have exuded from the alimentary canal, forming the equivalent of the nutritive fluid of the mollusc. The simple unarmed mouth (*m*), lying at the base of the tentacular hollow, communicates with a gullet (*g*), spacious stomach (*s*), and a long intestinal canal (*i*), partially lined with cilia. This, bending somewhat abruptly at the base, turns upwards, and terminates in an efferent orifice (*a*) close to the mouth, occasionally *within*, but usually *without*, the circle of gill-tentacles. The biliary glands are attached to the inner walls of the stomach. A single nerve ganglion (*g*), situated between the mouth (*m*) and the anus (*a*), with filaments radiating towards the tentacles and in other directions, represents the simple nervous system of the individual polypide. Both reproductive organs are generally present in the same individual. These consist of an ovary (*o*) attached either to the inner or body wall—or mantle lining of the cell—or above the spermary or testis (*v*) situated at the base of the perivisceral cavity (*d*), and connected by an elastic cord-like membrane (the funiculus, *z*) with the basal walls of the stomach.

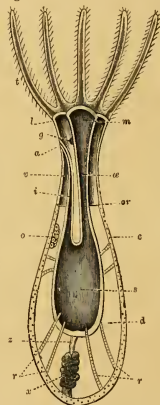


Fig. 20.—CELL AND ANATOMY OF A MOSS-ANIMAL. (Greatly enlarged, After Busk.)

t, Tentacles; *l*, Lophophore; *m*, Mouth; *g*, Nervous Ganglion; *a*, Anus; *or*, Oesophagus; *s*, Stomach; *i*, Intestine; *o*, Ovary; *v*, Testis; *z*, Funiculus; *or*, Orifice of Calcareous Cell; *c*, Ectocyst; *d*, Tentacular Sheath; *d*, Perivisceral Cavity; *v*, Retractor Muscles.

The muscles of the Bryozoon, composed of the simplest form of striated fibre, are numerous and well developed. Two pairs of retractors (*v*), arising from the bottom of the inner lining of the cell, are attached to the alimentary tube, and serve to retract the whole with its

crown of gill-tentacles within the cell-orifice (Fig. 20, *or*); others having a like base, are fixed to the disc or lophophore (*l*), and direct the rotary movements of the tentacular crown. Some dilate the flexible and reversible portion of the cell (*v*), maintain the tentacular sheath in its right position when everted, and withdraw it to again enfold the tentacles on their retirement. Not less important are those muscles which control the immediate expansion of the tentacles, and their separate or combined movements, or traversing the walls of the alimentary canal assist the processes of digestion. According to the observations of various writers, the Moss-animal, when desirous of bringing its crown of tentacles into communication with the water, in order to obtain the food and air necessary for its existence, commences to erect itself by slightly straightening the alimentary tube. The contraction of certain muscles called parietals, which permeate the mantle lining the cell, presses the fluid contained in the perivisceral cavity, or space lying between cell wall and intestine, upon the digestive organs. This pressure forces the tentacles to move upwards with the sheath, which is therefore pushed beyond the cell orifice until, more or less completely everted, it is held in place by its special muscles, and acts as a support to the alimentary organs of the little animal. The tips of the closed tentacles are the first to appear, and on the relaxation of the controlling muscles are rapidly unfolded and rotate with such speed and vigour as to create a perfect, if minute, whirlpool in their immediate neighbourhood. Into the vortex thus created by the movements of the cilia the small animalcules are engulfed, imprisoned within the circle of the ciliated breathing organs, and finally carried to the mouth. Then, if found suitable, they are swallowed by the muscular contraction of the walls of the gullet (*o*), and pass into the stomach. When the nutrient particles have been extracted the waste products are forced by the muscles of the digestive system into the lower portion of the ciliated intestine, and finally ejected at the anal orifice.

If sufficient food has been secured, or on the slightest alarm, the polypide is instantaneously drawn within the protecting cell by the action of the great retractor muscles (Fig. 21, *gr*), the tentacles (*z*) retire within the sheath (*sh*), which is again inverted, and its ridge closes the mouth of the cell in those genera in which it is otherwise unprotected. All the inhabitants of the colony may be expanded at once, and retreat one by one, or all at the same time, with the rapidity of lightning. Some are shy in their habits, and, once disturbed, are long before they again emerge and venture to display their glories; while others stand rough treatment, and do not long keep within the retirement of their tiny cellular habitations.

The hollow tentacles external to the closed sac, which is perforated only by the openings for the mouth and anus, are the most important structures in the Moss-animal economy. They serve as respiratory agents, thus corresponding with the gills of the Bivalve and the brachial appendages of the Brachiopod; but act also as organs of touch and prehension. They vary from eight to eighty in number, and originate from the disc or stage, the lophophore,* which roofs in the perivisceral cavity. As the lophophore is circular in most of the marine forms, the gill tentacles present a bell-shaped appearance (Fig. 18, *c*); but in many of the fresh-water genera it terminates in free ends forming the crescent or horseshoe-shaped crown, whence the name of Hippocrepian Bryozoa, often applied to this section of the class, is derived. There is no trace of the existence of a heart or vascular system, and the functions of circulation of the nutritive fluid are performed by means of the cilia clothing the membranous body wall lining the cell; circulation is, however, chiefly promoted by the muscular contractions of the mantle, which keep up an incessant current and movement of the fluid filling the perivisceral cavity. In this fluid the presence of white corpuscles has been detected.

One of the most important structures connected, not only with the life-history of each individual Moss-animal, but also with its relations to the rest of the colony, is that gelatinous tissue now known as the endosarc;† this consists of a cord-like prolongation of an elastic membrane (the funiculus, Fig. 20, *z*), which moors the base of the stomach to the bottom of the cell wall, and of divergent thread-like fibres, which, passing through the pores in the communication plates existing between the different cells,

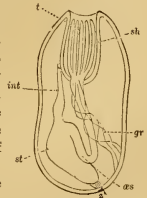


Fig. 21.—MOSS-ANIMAL RETRACTED IN ITS CELL.
(After Hincks.)

sh, Tentacular Sheath; *gr*, Great Retractor Muscles; *int*, Intestines; *st*, Stomach; *as*, Esophagus; *z*, Funiculus.

* Greek, *lophos*, a crest; *phero*, I carry.

† Greek, *endon*, within; *sarc*, flesh.

or through perforations in the stem partitions, link one Moss-animal to its neighbours, and thus unite the whole colony in a common life. The endosarc was at first considered to be the colonial nervous system, and to be associated with the singular phenomena of the regular and combined movements which occasionally agitate all the members of the same colony. But the researches of Joliet have proved that the tissue is not nervous in structure, and, according to this writer, the endosarc is a product of the mantle, originates the reproductive elements of the colony, and possibly enters largely into the composition of the tentacular sheath.

Such are the common attributes of a Moss-animal of the higher grade. In some forms, however, the pharynx (Fig. 23, *ph*) is more developed than in others, and the alimentary canal is divided into a

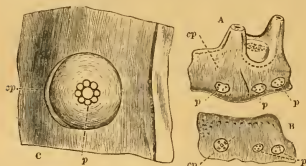


Fig. 22.—A, B, COMMUNICATION PLATES AND PORES IN CELL WALLS OF MEMBRANIPORA MEMBRANACEA; C, PERFORATED STEM OF ZOOBOTRYON. (After Reicher and Nitzsche).

cp, Plates; p, Pores.

existence distinguishes the "gullet-guarded" Moss-animals from those destitute of that structure; others, however, consider the epistome to be the equivalent of the foot of the mollusc, and there is no doubt that it serves as an organ of locomotion in that abnormal "mouth-footed" genus, *Rhabdopleura*, in which it retains its greatest development. (Fig. 18, A.)

Peculiar organs termed ovicells occur periodically in many Bryozoa of the first rank, in the form of external capsules or enlargements of the cell wall. They are often situated at the upper part of the animal chamber over-reaching its orifice. (Fig. 24, B.) These modified cells bud from the membranous walls of the cell and communicate with the perivisceral cavity. As their name implies, the ovicells retain the fertilised ova, which migrate into the pouch thus formed, and are finally liberated when fully matured as active ciliated larvæ. In a more complex form of ovicell the external opening of this brood chamber is closed by a membranous capsule furnished with muscles, by which it is withdrawn to facilitate the passage of the embryo Moss-animal into the sea-water. Occasional enlargements of the cell wall, and cells restricted to reproductive purposes, occur in some members of the inferior marine sub-orders. But the true "brood-chamber" or marsupium appears only in the most highly organised sub-order of "lip-mouthed" Moss-animals (*Cheilostomata*),* which are further characterised by the presence of two kinds of movable appendicular organs developed on the external covering of the colony, and irregularly distributed over its surface. The "vibraculæ" consist of a long slender bristle, thickest towards the base (Fig. 25, A, *v*), seated on a prominence in a hollow cup or receptacle—the representative of a cell—containing only the muscles which direct its lashing movements. Mr. Busk says:—"These whip-like appendages serve as defensive and cleansing organs, and may be observed in almost constant motion, sweeping slowly and carefully over the surface of the colony, and removing whatever might be noxious to the delicate inhabitants of the cell when the tentacles are protruded." In the family Selenariidae, which are never attached to foreign objects, even when adult, they are enormously developed, and serve as organs of locomotion, by means of which Mr. Busk has observed the colony to be transported from one locality to another.

The second kind is that one form of which was first recognised and described by Ellis, in a

* Greek, *cheilos*, lip.

higher or cardiac (*c, c*), and a lower or pyloric cavity (*p*). A gizzard is occasionally present in both marine and fresh-water forms, aiding the processes of digestion. Primitive excretory organs are also developed in the form of kidneys in some species. Many Bryozoa are further characterised by the presence of a valvular organ, the epistome, situated on that side (neural) of the mouth nearest to the nerve centre. This singular organ (Fig. 18, *e*) has been compared with the epiglottis of the throat of mammalian animals. It is moved vigorously up and down when the alimentary organs are partially protruded from their cells. Regarded by some as an organ of sense, it acts as a protection to the entrance of the gullet (*ph*), and its



Fig. 23.—ALIMENTARY CANAL OF CELLEPORA. (After Hincks).

c, c, Cardiac; p, Pyloric cavity of Intestine.

species to which he gave the name of the "birds'-head Coralline." They are known as "avicularia," from the strong resemblance the most perfect present to a bird's beak, and are always composed of a chamber lodging muscles, and sometimes a tiny tuft of bristles seated on a prominence—possibly a tactile organ of sense—a more or less developed mandible, and a horny beak which can be brought into, and withdrawn from opposition, by means of two sets of muscles. The avicularia are of three distinct types, progressing from the rudimentary form of a dwarfed cell of the colony with an enlarged lid or operculum—"the immersed" (Fig. 24, B, d)—to those seated on the cell wall with a small chamber and mandible—the "sessile" (Fig. 25, B)—up to the ultimate type, "the pedunculate" (Fig. 25, C), which are situated on a movable jointed stalk, look like a bird's head, and sway to and fro snapping their jaws incessantly. These stalked forms have been credited with an alimentary function, for they seize small organisms, usually worms, and retain them pertinaciously in spite of their vigorous efforts to escape. But it is evident that they are not able to convey them to the mouth, which is, moreover, too small to swallow the objects generally captured. In accordance with the views of Mr. Hincks, the ciliated tentacles are sufficient to secure regular nourishment for the animal, and the avicularia are charged with a purely defensive function. "They may either arrest or scare away unwelcome visitors. Their vigorous movements, and the snapping of their formidable jaws, may have a wholesome and deterrent effect on loafing annelids, and other vagrants; whilst the occasional capture of one of them may help still further to protect the colony from dangerous intrusion."

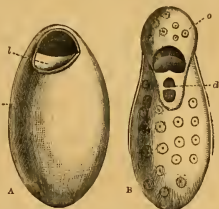


Fig. 24.—CELLS OF CHEILOSTOMATOUS BRYOZOON. (Enlarged after Busk.)
c, Animal Cell; l, Lid or Operculum; a, Ovicell; d, Immersed Avicularia.

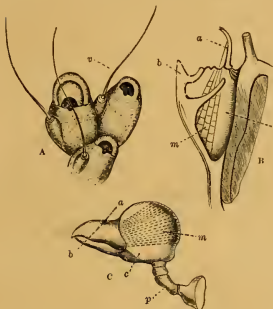


Fig. 25.—A, PORTION OF POLYZARIUM WITH VIBRACULE, v. (After Hincks.) B, SESSILE, C, PEDUNCULATE AVICULARIA. (Enlarged after Busk.)
a, Mandible, b, Beak, c, Chamber, m, Muscles, p, Peduncle.

also linked by a series of transitional forms with the vibracular organs, which likewise consist of a chamber lodging muscles, and a movable bristle. Mr. Hincks describes the vibracule as acting sometimes independently of each other, and at others in combined action, as though swayed by a sudden impulse, yet with the perfect regularity and order of a machine. From this fact he derives an argument in favour of some kind of colonial sensation and means of communication. The occasional simultaneity of the movements of the vibracule was also noted by Mr. Charles Darwin,* who gives an interesting description of both kinds of the

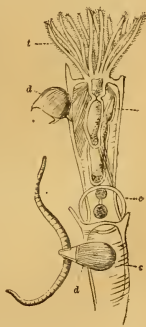


Fig. 26.—CELLS OF BUGULA AVICULARIA, WITH AVICULARIA (d) HOLDING A WORM. (After Busk.)
c, Cell, a, Ovicell, t, Tentacles, d, Avicularia.

* "Voyage of the Beagle," p. 201.

appendicular organs as observed by him in living specimens, off the coast of Tierra del Fuego in 1846.

The subjoined table gives the classification of the Sea-mosses, and the approximate inter-relationships of the minor groups, commencing with the higher forms. Sub-orders and genera known to be represented by fossil species are printed in *italics* :—

HOLOBRANCHIATA	ECTOPROCTA	<i>Cheilostomata</i> , marine, <i>Flustra</i> , <i>Bugula</i> , <i>Cellepora</i> , <i>Membranipora</i> .
		<i>Cyclostomata</i> , marine, <i>Stomatopora</i> , <i>Hornera</i> , <i>Fenestella</i> , <i>Lichenopora</i> .
		<i>Ctenostomata</i> , marine, <i>Bowerbankia</i> , <i>Victorella</i> , <i>Mimosella</i> .
		<i>Paludicella</i> , fresh-water, <i>Paludicella</i> , only.
		<i>Lophophea</i> , fresh-water, <i>Lophopus</i> , <i>Alcyonella</i> , <i>Plumatella</i> , etc.
	ENDOPROCTA	<i>Pterobranchiata</i> .
		<i>Podostomata</i> (mouth-footed).
		<i>Rhabdopleura</i> , marine, only.*
		<i>Cephalodiscus dodecatophus</i> .
		<i>Loxosoma</i> , marine.

ORDER HOLOBRANCHIATA.

THE ECTOPROCTA.—THE CHEILOSTOMATA.

Members of this highly-organised group are usually, as their name implies, distinguished by the presence of a horny lip or shutter, which, moved by special muscles, effectually closes the orifice of the cell on the withdrawal of its animal occupant. The external layer of the cell wall (ectocyst), sometimes fleshy or horny, is more often of a calcareous nature. The Cheilostomata are further characterised by the frequent presence of those singular outgrowths of the colonial skeleton—the vibracular and avicularian appendages already described. The former occur more frequently than the latter, with which, moreover, they are occasionally associated. The bases of these organs—often preserved in a fossil state—aid in the determination of genera. The marsupium, or “brood-chamber,” also distinguishes these Moss-animals, which undoubtedly exemplify the most perfect form of bryozoonal organisation, although, at the same time, that which—furthest removed from the molluscan type—illustrates the effects of degeneration resulting from the adoption of a stationary life. In Moss-animals with a circular-mouthed cell (*Cyclostomata*, Fig. 27), the ectocyst is likewise more or less encrusted with a calcareous secretion, and the orifice of the usually long and tubular cell is generally unprotected by any apparatus for its closure and protection of the more simply-organised animal. But members of this group occasionally possess a modified operculum, which links them



Fig. 27.—STOMATOPORA DICHO-
TOMA. (After Zittel.)
GREAT OOLITE.

with the perfectly “lip-celled” Moss-animals, some of which in turn present external features of the *Ctenostomata* † (Fig. 28), a third sub-order, which includes a number of remarkable species, for some are fleshy, irregular, and spongy; others horny, plant-like, with flexible movable cells. The ectocyst, never calcareous, is either of a horny-membranous or membrano-gelatinous nature, and in many cases the cells arise at intervals from a creeping tubular stem, the stolon (Fig. 28, s). A portion of the tentacular sheath is fringed with a row of bristles connected by a thin membrane, which, drawn together on the retreat of the polypide, closes in and forms a hairy operculum or “comb-like” protection above the tentacles when those organs are retracted within the lower and harder portion of the cell. Some species inhabit brackish water, and exhibit modifications of the tentacular crown and other resemblances to the fresh-water forms.

The sub-order *Paludicella*, is at present represented by a single, branched, fresh-water Moss-animal, which, of timid habit and a lover of obscurity, dwells in slowly-running waters, whence its generic name is derived. The animal of *Paludicella* inhabits a club-shaped, divided cell. The loop is circular, and, like all the foregoing members of the Gymnolematous section, the gullet is unprotected by the “epistome.” All the remaining Ectoproctous forms are comprised within the sub-order *Lophophea*, founded on the genus *Lophopus*—the famous “Bell-flower” animal first

* A second supposed fresh-water Pterobranchiate has been described by Mr. Hincks, from Canada. † Gr., *kteis*, a comb.

described in 1741 by Trembley. In these "gullet-guarded" (Phylactolemata) genera the epistome is developed, and, as the arms of the lophophore are either free or suppressed, the tentacles usually assume a "horseshoe-" or crescent-shaped crown. (Fig. 18, B.) This sub-order includes a number of interesting forms, generally fungoid, gelatinous, limpid, or of a green, brown, or yellowish-white colour. The majority are timid, light-shunning animals, and once disturbed are long before they venture again to expand their tentacles. The wandering *Cristatella* (Fig. 17) forms an exception to the rule, and seems capable of existing only in the full influence of sunlight in a whirlpool caused by the ceaseless agitation of its constantly-expanded crown. The fresh-water genera, to quote their chief historian, Dr. Allman, "may be sought in the still and running waters of the land, in the broad river and the rushing stream, in the pure cold mountain lake and the stagnant waters of the moory fen. In interest they yield not one jot to their brethren of the sea, and offer to the naturalist an inexhaustible source of gratification in the beauty of their forms and the wonders of their organisation."

THE ENDOPROCTA.

In this secondary group of inferior Moss-animals the anal orifice occurs *within* the tentacular crown instead of outside of it. In the single sub-order *Pedicellina* the tentacles are developed from the two sides of the upper margin of the cup-shaped cell. When at rest they lie partially concealed within the vestibule, as there exists no sheath into which they could be retracted. The animal does not leave the cell, and no muscles for its protrusion and retraction are developed. The ectocyst, or investing integument, is soft throughout, remaining entirely unhardened by a secretion of a calcareous or other nature. It closely surrounds the alimentary canal, and there is no true body cavity. The animal chamber is seated on a long contractile stem, from which it is generally separated by a diaphragm or partition. This peduncle (Fig. 29, *p*), sometimes furnished with spines, is very muscular towards the base, and capable of vigorous movement. The various members of the colony are united by the creeping tube or stolon (Fig. 28, *s*), from which the supporting peduncles spring at intervals. They often swing to and fro so actively that the colony resembles "a field of corn agitated by the wind;" and the muscular movements continue after the death of the animal inhabitant of the cup-shaped cell at the free end of the stem, which periodically falls away, and is reproduced by internal budding. Besides the marine *Pedicellina*, and a similar "urn-shaped" (*Urnatella*) fresh-water genus, this sub-order comprises a singular bi-sexual genus, the only known solitary Moss-animal. It lives fixed by a pedal gland—the representative of the molluscan shell-gland—attached to the caudal extremity of worms and other marine animals. The

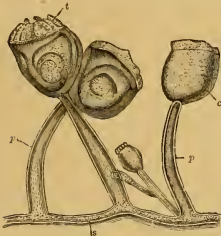


Fig. 29.—ENDOPROCTOUS TYPE ($\times 100$),
PEDICELLINA CERNUA. (After Hincks.)
s, Stolon; *p*, Peduncle; *c*, Cell; *t*, Tentacles.

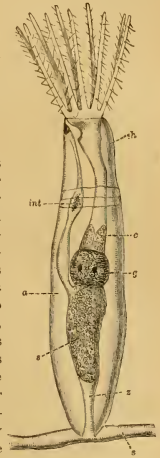


Fig. 28.—BOWERBANKIA.
(A. Farre. Enlarged after Hincks.)
sh, Tentacular sheath; *c*, Cell wall; *s*, Stolon; *c*, Cauda; *g*, Gizzard; *z*, Funiculus; *int*, Intestine.

caudal extremity of worms and other marine animals. The tentacles of *Loxosoma* are obliquely developed, and the body-cavity is attached to a contractile stem without any intervening partition. It is also devoid of the creeping tube or stolon.

ORDER PTEROBRANCHIATA.

In the "mouth-footed" sub-order (Podostomata) the breathing organs arise from a winged or divided base (Fig. 18, A), and the mouth of the Moss-animal is situated under an enormously-developed organ, believed to be the equivalent of the "epistome" characterising the fresh-water genera. It serves as a foot, enabling the animal to walk up the walls of its long and tubular cell, to which it

is attached solely by the contractile "rod-like" funiculus. There is no mantle or inner layer of the cell-wall, and the cavity becomes filled with sea-water. No muscles are developed, the animal raising itself in the cell by means of the foot. Protrusion, a slow process, takes several hours to accomplish, and the animal is retracted by the elastic funiculus. The detached bud is furnished with two valve-like fleshy plates. The unique *Rhabdopleura* has been dredged in the British and northern seas in from ten to three hundred fathoms. Although a marine form, according to its describers, Sars and Allman, it presents many resemblances to the fresh-water genera, and is the representative of a very old type. It is supposed that the *Graptolites* are allied.

The Moss-animals sustain life under the most variable conditions of temperature and depth. Some affect shallow, muddy waters, others the regions of clear water or strong currents, and several species exist in the dim and unruffled abysses of the ocean. They are numerously represented in temperate regions, in the frozen waters of the east Greenland coast (*Kirchenpauer*), and in the warm latitudes of the Australian shores. They encrust the floating Gulf-weed with their silvery network, and grow on reefs between and on the different clumps of coral. Many species are universally distributed, others characterise boreal regions or the tropical zones. One, at least, leads a roving existence, and attached to the keels of ships is borne from clime to clime. The *Cheilostomata* and *Cyclostomata* are specifically most abundant from between tide marks to depths of 200 fathoms. They are somewhat less frequently recorded from 200 to 600 fathoms. A few species of the "lip-mouthed" forms frequent the brackish waters of friths and the mouths of tidal rivers, but the deep-sea species appear as usual to be widely diffused. Those dredged by H.M.S. *Challenger* have been described by Dr. Busk, and the occurrence in the Atlantic of several of the "lip-mouthed" sub-order at depths varying from 1,500 to 3,000 fathoms is noteworthy. Among these abysmal forms was a species of a cosmopolitan genus, with a range from shallow water to great depths, and closely allied to members of a group that existed in Cretaceous oceans. This was brought up from between 2,000 and 3,000 fathoms, in a sterile region where other animal life was scarce. A peculiarly interesting and novel species (*Kinetoskias cyathus*), arising from fibrous roots possessing the long, slender stem of the *Endoprocta*, supporting branches forming a cup, yet characterised by the colonial growth and appendages of the most highly organised class, was dredged in 1,500 fathoms off the Island of St. Vincent, and elsewhere in 2,650 fathoms. The *Ctenostomata* and other marine forms apparently prefer depths under a hundred fathoms. Two hundred and thirty species in all occur in the British seas. The fresh-water genera are distributed in the still and running waters of Europe, India, and North America, at depths ranging from a few inches below the surface to four feet.*

Although the *Bryozoa* are of comparatively little importance as reef-builders in the present day, in past ages beds of limestone of considerable extent and thickness were built up by their exclusive agency. Fragments of the calcareous or horny skeletons of the "lip-" and "circular-mouthed" species remain when the soft parts decay, and, frequently, preserved in a fossil state, testify that genera closely allied to living species have existed even from early epochs. Excluding a doubtful Cambrian form, we find a large number both of the erect and net-like forms (*Retepora*, *Fenestella*), and the delicate encrusting types, in rocks of Lower and Upper Silurian age. Some of these died out, others persisted, and many new forms appeared in the succeeding Devonian and Carboniferous epochs. Closely-related forms occur in the Trias. During the Mesozoic period, the Moss-animals contributed largely to the formation of extensive deposits, and attained their maximum. Jules Haime has described a number of Jurassic species, and D'Orbigny figured eight hundred from the Cretaceous rocks of France alone. Some Palæozoic and Mesozoic genera (*Stomatopora* and *Diastopora*) still continue to be represented; while the perforating *Hippothoa* has persisted from the Silurian, but the majority of generic forms are restricted to one life-epoch, and many occur only in a single geological horizon. *Bryozoa* abounded in the Miocene, and many species from the later Tertiary deposits are stated to be closely allied to, and even identical with, species living in the present oceans.

* In Vol. xx. of the *Challenger Reports* (Zoology), Prof. McIntosh and Mr. S. W. Harmer described, from 245 fathoms in the Straits of Magellan, a remarkably abnormal colonial *Bryozoon* (*Cephalodiscus dodecalophus*) with a notochord and a pair of gill slits and allied to *Rhabdopleura*.

The soft and perishable nature of the common dermal covering in the Ctenostomata and Endoprocta would preclude their preservation in a fossil state. But it is highly probable that these sub-orders also existed in past ages. For the structure and embryological history of the few existing species belonging to those groups seem to indicate that they represent the earlier forms of Bryozoan life, when the primitive types were free when adult, as the ciliated larva is in the first stages of development. Thus the fixed state and colonial growth may be regarded as modifications occurring in the course of generations. The first kinds were probably solitary animals, the first step towards colonisation being the development of that creeping tube, the stolon, which unites the various shoots or cells into a colony of individuals, as in *Pediclellina* and the Ctenostomatous forms. Thence all the varied colonial types may have differentiated, and all the organs for the protection and common welfare of the colony were eventually developed.

Differences in the form of the colony of parasitic species often result from the shape of the organisms they infest, and singular modifications adapted for the life that is led are of frequent occurrence. Thus, in a species of *Membranipora* which forms conspicuous white patches upon the Gulf-weed, and other Algae, the skeleton is not universally hardened throughout. Certain parts remain flexible and so escape fracture, when the thousands of united cells sway backwards and forwards in the water, as the fronds of the weed are tossed to and fro by the waves. The shape of the erect colonies depends chiefly upon the mode in which the budding takes place, and the situation of the primary buds. In radiating and crust-like species, new cells often become interpolated. One of the common Sea-mats grows so rapidly during the summer, according to Nitzsche, "that the edges present a remarkable appearance. A marginal zone of perhaps one inch in breadth contains only half-developed cells; those nearest the centre, being least maturely calcified, are inhabited by smaller polypides; the younger ones are still uncalcified, and the cell orifice being as yet undeveloped, they cannot protrude. Only a very small part of a marine colony contains completely developed polypides. The younger cells at the extreme edge enclose immature buds, the older are empty, and only those cells intermediate between the elder and the younger contain fully developed animals."

Internal buds, called "Statoblasts," enclosing between two valve-like plates a polypide, which remains in a quiescent state for a variable period, are also developed on the "funiculus," and liberated as perfected Moss-animals, on the death of the parent. These are characteristic of the "gullet-guarded" fresh-water genera, some of which also multiply by fission—a form of budding in masses. The life-history of the marine colonies, is likewise perpetuated by internal buds in each cell. The chief features of this singular process, known as "the fall and renewal of the polypide," have been minutely described by F. A. Smitt, but are still the subject of controversy. It appears certain, however, that on the dissolution of the polypide, a portion of the digestive organs separates from the rest, and remains attached to the funiculus, a part of the endosarc, or common internal flesh of the colony. This "brown body," or remnant, increases in size, at the expense of the fatty globules by which it is surrounded, and is believed to give rise to a bud which develops into a perfect Moss-animal, resembles its predecessor in the cell, and may profit by the perfections of the colonial system. For, strange to say, the avicularian and vibracular appendages are not affected by the death of the animal inhabitant of the cell on the outer wall of which they may be developed, their existence being independent of it, and connected with the colonial system of which they are the outgrowths.

Thus is the increase of the colony secured, and the life-vigour of its inhabitants renewed and perpetuated. A word as to its original development. In most Moss-animals, both reproductive elements are present in each cell. But there are a few exceptions to the general rule, as among some of the Sea-scurfs, the Ctenostomata, and in the solitary *Loxosoma*, in which the sexes are stated to be distinct, the tufts of separated animals consisting either of male or female individuals. Sometimes the ova, fertilised either before or after their expulsion in the water, are set free in the perivisceral cavity, and escape only upon the rupture of the sac, and death of the parent polypide. Or they are dispersed by means of special organs, or pass through the brood chamber, and a period of further development. But in all cases they finally reach the water, as more or less developed, active, free-swimming larvæ. In this state they pass a variable period of time, swimming about by means of the cilia with which they are clothed. Eye-spots are developed, and long bristles for touch and guidance. These are absorbed when the little animal abandons its free life, becomes stationary, and develops into the

primary polypide, and foundation cell of the colony. But before reaching this stage, the embryos pass through a number of phases of development, which, although varying according to the nature of the genus, may be all regarded as derived from a primitive ideal type (Jules Barrois). The wandering, segmented, ciliated, larvæ endowed with temporary organs of sense, present a remarkable similarity to those of the Brachiopoda, and the presence of a bivalve shell in some species of Bryozoa, as well as the "horseshoe" stage of the loop amongst the Brachiopods, are further embryological points in common.

The anatomical features of adult individuals of each class are, moreover, very similar. Both the Brachiopod and the Moss-animal breathe and obtain nourishment by means of the pliant, tentaculated organs clothed with cilia which are protruded for that purpose, although the action in the former is constrained by the spiral shape of the fleshy, respiratory, and food-securing organs, and the rigidity of the internal skeleton often supporting them within the mantle cavity. Neither possesses a heart, and the nutritive fluid is circulated entirely by ciliary, or ciliary and muscular action. In both groups a mantle is usually developed, and there is a close identity of type in the structure of the digestive organs, which, among the Brachiopoda, are attached to the inner wall separating the body or perivisceral cavity from the mantle chamber by muscular bands—the equivalents of the funiculus of the Bryozoa. "A certain parallelism may also be suggested between the leading groups of the Bryozoa and the Brachiopods. We have forms like *Lepralia*, attached by the region of their shells, this shell being calcareous, and exhibiting minute punctures which have been compared to similar markings in certain Brachiopods. So among the latter group do we find forms attached, as in *Thecidium*, and some species of *Productus*; and generally the articulated Brachiopods might be compared to such forms as *Lepralia* (a Sea-scurf); while on the other hand such genera as *Pedicellina*, with its long, pliant, and muscular stalk, or *Loxosoma*, with a stalk highly retractile, may be compared to *Lingula*." (Morse.)

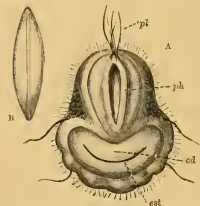


Fig. 30.—A, FREE-SWIMMING CILIATED CHEILOSTOME LARVA. (After Barrois.) B, STATOBLAST OF FREDERICELLA. (After Allman.)

pi, Ciliary plume; ph, Pharynx; est, Stomach; cd, Digestive Cavity.

It is evident, therefore, from embryological development and adult organisation, that the Brachiopoda and Bryozoa are so closely allied as to form a very natural group, and thus are they classed by the majority of authors. With regard, however, to the exact position in the animal kingdom to be occupied by the group thus restricted, opinions are far less unanimous; for it is also certain that in their earliest stages of growth the Brachiopoda and Bryozoa betray no molluscan characters. In fact they present such a close resemblance to similar stages of some worms, that such embryological authorities as Steenstrup, Morse, Kowalevsky, and Agassiz, deny their right to admission to the molluscan type. Professor Morse deduced the same conclusion from observations of the habits and structure of full-grown *Lingula*. But other zoologists consider these structural affinities merely as throwing light on the geological ancestry of both of these coeval types of organisms.

The literature of the Moss-animals is very copious. I am indebted, among others, to the following standard works:—"A History of the British Marine Polyzoa," 1880 (Thomas Hincks); "A Monograph of the Fresh-water Polyzoa of Britain" (J. G. Allman); "Catalogues of the Species of Marine Polyzoa in the British Museum" (G. Busk); and to the same author's contributions to the "Transactions of the Microscopical Society." For the history of the fossil forms of the class, I am indebted to the well-known works of Alcide D'Orbigny, Jules Haime, and the publications of the Paleontographical Society (G. Busk); for anatomical details, to the memoirs of Dr. Arthur Farre, P. J. Van Beneden, Karl Vogt, and T. Hincks, and the works of F. A. Smitt, Nitzsche, Ray Lankester, Morse, Vine, McIntosh, and Harmer; and for embryological details, to the complete "Embryologie des Bryozoaires" of Jules Barrois. To the Rev. T. Hincks, M.A., F.R.S., Dr. Jules Barrois, and also to Dr. A. Fritsch, Dr. Kirchnpauer, M. P. J. Van Beneden, and Dr. E. Von Martens, I wish to express my thanks for assistance and further information.

AGNES CRANE.

CLASS INSECTA.

CHAPTER I.

ANATOMY OF INSECTS.

Characteristics of the Arthropoda.—Insects—Divisions of the Body—Segments of the Abdomen—Structure of the Thorax—The Jointed Limbs—Parts of the Leg—The Feet—The Wings—The Head—The Antennae—The Organs of the Mouth—Segmentation of the Head—Modifications of the Mouth in Sucking Insects—The “Moulting”—The “Transformations” of Insects: Larva, Pupa, and Winged Stages—Internal Anatomy—The Nervous System—Structure of the Eye—Function of the Antennae—The Digestive System—The Circulatory Apparatus—How Respiration is Performed—Reproduction—Classification.

THE Arthropoda,* as already stated in the Introduction to Invertebrate animals in general, are characterised by having the integument of the body divided into a series of rings, generally hardened

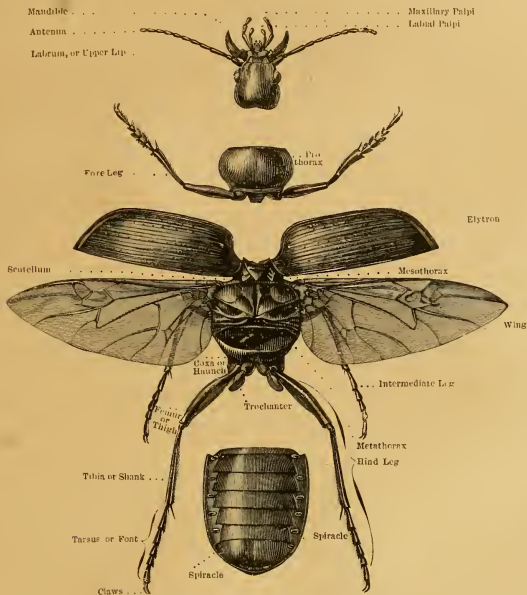


Fig. 1.—BEETLE (*Calosoma sycophanta*) WITH THE HEAD, THE PORTIONS OF THE THORAX, AND THE ABDOMEN SEPARATED AND MAGNIFIED.

by deposition either of the horny substance, called *chitine*, of which the outer skin of these animals fundamentally consists, or of carbonate of lime, and united by soft flexible portions of the skin, which enable the parts to move more or less freely. These firm rings are called *segments*, or, by many anatomists, *somites*, and also *metameres*, as being more or less repetitions of similar parts. So far the Arthropoda agree with many Vermes, and in the older classifications the Arthropods and Vermes

* Greek, *arthron*, a joint; *pous*, a foot.

constituted two divisions of a single group (Annulosa), the leading idea in the foundation of which was the division of the body in this way into a series of segments, the greater part of which might be almost exact repetitions of each other. In the Arthropods, or jointed-limbed animals, however, we find, superadded to the simple Annulose type of structure, a greater or less number of jointed limbs serving the animal for progression either in walking or swimming.

Of the Arthropoda thus characterised the creatures known as Insects constitute the highest or most highly specialised type. They may be roughly defined as Arthropods in which the body is distinctly divided into three parts, called the head, the thorax, and the abdomen, furnished with three pairs of jointed limbs attached to the second division of the body, and breathing air by means of fine tubular organs which ramify in all parts of the body. Besides the legs the thorax generally bears one or two pairs of wings; the head has only a single pair of the organs known as *antennæ*; and the segments of the abdomen, or third division, have no limbs attached to them. These statements apply to the insect in its adult or perfect state; at earlier stages of its existence, as will be seen hereafter, it may present very different characters.

The segmented structure is most plainly shown in the abdomen (Fig. 1), and we will therefore commence by describing its general characters. There are usually no more than nine segments in this part of the body, and of these some are often suppressed or greatly reduced in size and concealed by others, so as to make the abdomen appear to consist of fewer than the theoretical full number of rings. In certain insects, on the other hand, there are, beyond the true ninth segment, certain parts which are regarded as representing two more segments, thus giving eleven as the total number of such parts that may exist in the abdomen of an insect (Fig. 2).

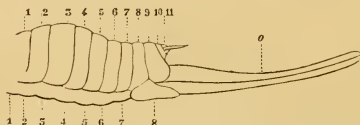


FIG. 2.—SIDE VIEW OF ABDOMEN OF DECTICUS, SHOWING THE SEGMENTS.
o, Ovipositor.

The segments of the abdomen, as already stated, bear no jointed organs of the nature of limbs, but at the extremity of this part of the body we not unfrequently find certain appendages (jointed tails, ovipositors, claw-like pieces, &c.). The abdomen may be attached to the next division of the body (the thorax) by its whole breadth, or the segment or segments towards the base may be more or less narrowed, so that not uncommonly the actual union is effected by a very thin stalk. The segments themselves are composed

of two half rings placed on the upper and lower surfaces (dorsal and ventral plates), and these may be firmly united to each other at the sides, or attached by a flexible membrane similar to that by which the successive segments are joined. In some cases where the wings form a protective covering for the abdomen (as in Beetles), the upper surface of the abdomen shows no horny plates, but is covered with a soft flexible skin.

The *thorax* (Fig. 1) consists always of three segments, but, although in many insects this structure is as plainly recognisable as in the abdomen, it is very often masked, or even partly concealed, either by the close union of the segments, or by the shifting of the position of the parts of which the segments are composed, for the thoracic segments are more complex than those forming the abdomen. Thus in a perfect thoracic segment we can distinguish a dorsal plate (*notum*), and opposite to it a *sternum* (or "breast-bone"), and uniting these on each side two other pieces (*pleuræ*) placed one behind the other, of which the foremost is called the *episternum*, and the hinder one the *epimerum*. All these lower pieces generally take part in forming the socket for the attachment of the limb; they are united by sutures, but frequently so amalgamated together that the whole thoracic segment seems to form a complete ring. The three segments of the thorax are indicated in descriptions by distinctive names; the foremost is the *prothorax* (Fig. 1), the second the *mesothorax*, and the third the *metathorax*. In like manner the two principal pieces of which each successive segment is composed are distinguished as the *pronotum*, *mesonotum* and *metanotum*, and *prosternum*, *mesosternum*, and *metasternum*. In many cases the mesonotum exhibits in its middle a small raised plate, called the *scutellum* (Fig. 1), which is well seen in most Beetles; and in some insects a similar elevation is presented by the metanotum, the *post-scutellum*.

It has already been remarked that the thorax bears the three pairs of jointed limbs which are characteristic of Insects. One pair of these organs is appended to each segment of this division of the body, and thus the original division into three segments may be indicated even when the amalgamation of the segments themselves appears to be most complete. These limbs are inserted into sockets on each side of the sternum by means of their first joints, which may be spherical, or nearly so, and thus enable the limb to turn in any direction, or more or less elongated or ovate in form, when the movement of the limb from the socket will be more like that of a hinge. These first joints, called *coxae* (Fig. 3, *a*), are followed by a piece usually of small size, the *trochanter* (*b*), which may be a ring-like joint uniting the coxa to the following joint of the leg, or a more or less triangular plate extending along part of the under surface of the latter. The third piece, generally the largest and most powerful joint of the leg, is the thigh or *femur* (*c*), at the apex of which the shank or *tibia* (*d*) is articulated by a hinge joint. Both these parts, but especially the tibia, are frequently armed with spines and bristles; the tibia in particular are very commonly furnished at their extremities with movably articulated *spurs*, which project considerably, and materially assist the insect in walking. The actual foot, or *tarsus* (*e*), is attached to the extremity of the tibia, and is composed of a variable number of joints, but never more than five. The joints of the tarsi often vary much in size and form, even in the same insect or in the same tarsus; they are generally clothed beneath with short stiff hairs, or modifications of hair-like structures, and the last joint bears at its apex a pair of movable claws, between or beneath which in the majority we find small membranous appendages, which are called *pseudonychia*, or *arolia*.



Fig. 3. — WALKING LEG OF COCKROACH.

These jointed limbs are modified in a great variety of ways, and their peculiarities of form and structure are of much importance in the classification of insects. Their chief use being for walking or running, they are, in the majority of these animals, subject only to minor modifications of the whole organ, or some of its parts; but where special functions have to be performed by them the changes are much greater. In this way the legs, or some of them, may be strongly compressed and widened, and provided with strong fringes of bristles to fit them for natatorial purposes, as in the Water-beetles; or shortened and thickened, furnished with great cylindrical coxae, broad, toothed tibiae and short concealed tarsi adapting them to the purpose of digging, as in the Mole-cricket; or elongated, and provided with very powerful thighs for jumping, like the hind legs of Grasshoppers and Locusts; or furnished with very long coxae, thighs grooved and spined beneath, and tibiae and tarsi arranged to fit into the groove of the thighs, rendering them formidable prehensile organs, of which the fore legs of the so-called Praying Insects (Mantide) are examples. Of the infinity of minor modifications, elongations, or abbreviations of parts, partial dilatations and contractions, development of bristles and spines, &c., there is no occasion to speak here; examples enough of them will have to be described in characterising the insects in which they occur.

Besides the legs the thorax usually bears one or two pairs of wings—in fact, in the majority of adult insects the whole of the organs of locomotion are confined to this region of the body. The front pair of wings when there are two pairs spring from the mesothorax, and the second pair from the metathorax, and always from the junction between the dorsal plate (*notum*) and the pleure. They are generally thin membranous organs, and notwithstanding their delicacy they consist always of two membranes continuous at their edges, and firmly attached to each by their inner surfaces. This peculiarity of construction is explained by the mode of formation of the wings. These are originally sac-like dilatations of the integument, which gradually become extended and more delicate in texture, until the inner surfaces come in contact and adhere one to another; but this does not finally occur until after the insect has arrived at maturity, and the two membranes, of which the wing is composed, can be at first easily separated. In most cases the wings are traversed by a greater or less number of veins, which branch in various ways, and generally form a sort of network. These veins consist primarily of air-tubes, similar in construction to those which ramify through all parts of the body, and serve, as will be described hereafter, for the purpose of respiration, and passing out of the thorax into the wings, spread out there between the two membranes. They are usually thickened by an increased deposition of horny chitine along their course, and as

this is usually of a blackish or brownish tint, the wing-veins become plainly marked. The mode of ramification of these veins is exceedingly characteristic of different groups of insects, and consequently of great importance in their classification. In some cases the deposition of horny material in the wing is not confined to the veins, but extends throughout the wing, which then becomes a horny or leathery organ, unfitted to assist in flight. This change usually takes place in the fore wings

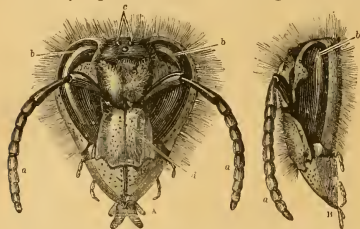


Fig. 4.—HEAD OF HORNET (*Vespa crabro*) ENLARGED, FRONT (A) AND SIDE VIEW (B).

a, Antennæ; b, eyes; c, Ocelli; d, Clypeus, which in the Front View conceals the Labrum

alone; and in the Bugs only the first portion of the wing becomes horny, and the overlapping terminal parts are membranous. Such fore wings are called *tegmina* and *hemelytra*.

Exceptionally many insects belonging to the most various groups, are always wingless, or the males are winged and the females apterous; and besides these certain entire groups, especially of parasitic insects, contain none but apterous species. Either of the pairs of wings may become greatly reduced in size, and apparently useless, while the other pair is fully formed; and in one whole order the fore wings alone are developed, and the hind wings are represented by a pair of small organs, consisting of a slender stalk, terminated by a little knob, which have received the name of *halteres* or *balancers*.

The *head*, or the foremost of the three divisions of the body (Fig. 1), when examined as a whole, appears to be a solid horny case, but a consideration of its appendages leads to the conclusion that it is composed of several segments.

On the upper surface or at the sides it bears a pair of jointed organs called *antennæ* (Fig. 4, a), and a pair of *eyes* (b), which are almost always of the kind called compound; beneath it shows the organs of the mouth, which are subject to the most remarkable modifications.

The apparently homogeneous case of the head is considered to be divisible for descriptive purposes into various regions; thus the space between the eyes is called the *forehead*, in front of which is a part known as the *clypeus* (d), and the two together form the *face*. The crown of the head is called the *vertex*. Immediately in front of or beneath the clypeus, closing the mouth in front, is a small plate, usually movably articulated, and called the upper lip or *labrum*. On the vertex there are in many insects two or three simple eyes, or *ocelli* (c), the general structure of which and of the larger compound eyes will be explained farther on.

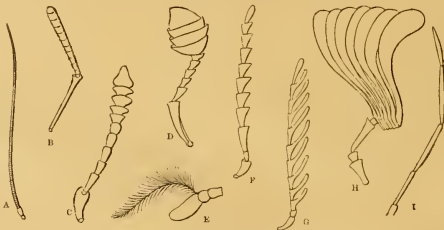


Fig. 5.—VARIOUS FORMS OF ANTENNÆ.

A, Locustæ; B, Apis; C, Silpha; D, Nereophorus; E, Volucella; F, Elater; G, Cicnocras; H, Melolontha; I, Aegus.

The *antennæ* (Fig. 5), which are attached to the head either in front of or between the eyes, are jointed organs of the most various development; sometimes excessively long, and many-jointed; sometimes very short, and composed of but few pieces; sometimes thread-like or necklace-like, and composed of joints of nearly equal thickness throughout, or tapering more or less towards the extremity; sometimes clubbed at the end by the enlargement of a certain number of the terminal joints, or gradually swelling from the base to near the extremity; sometimes serrated or feathered on one or both sides by the emission of more or less fine processes from the joints, or foliated by the widening of such processes into leaves, which may be more or less separated or pressed together, like the leaves of a book. In many cases, the first joint is longer and more robust than those which follow it; and sometimes the latter are attached to the first joints at an angle, instead of being continuous with it; such antennæ

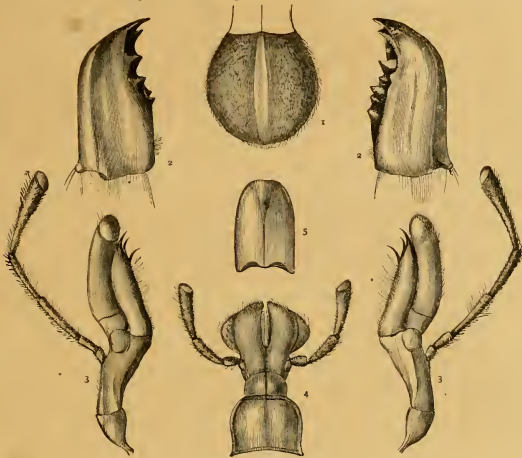


Fig 6.—ORGANS OF THE MOUTH.

1, Labrum, or Upper Lip; 2, Mandibles; 3, Maxillæ; 4, Labium, or Lower Lip; 5, Tongue.

are called kneed, or geniculate, and may be well seen in the common Ants. The differences of the antennæ furnish characters of great systematic importance.

The organs of the mouth (Fig. 6) must now receive our attention. The labrum, or upper lip, has already been mentioned. It is a small plate, usually of horny texture, articulated to the clypeus, but sometimes amalgamated with it, and really belonging to the head, although functionally forming part of the mouth. Immediately behind the labrum, in the mouth of a biting insect, we find a pair of solid horny organs, articulated to the head by a hinge-joint. They are often of considerable size, pointed at the apex, and armed with teeth, rendering them formidable weapons; at other times, shorter, and adapted rather to the gnawing of vegetable substances; but in all cases they are simple organs with no jointed appendages of any kind. This first pair of jaws is called the *mandibles*.

The jaws of the second pair, or the *maxillæ*, are by no means so simple, and in them we may trace some homology with the limbs attached to the thoracic segments. Thus the first joint of these jaws, the hinge-joint (*cardo*), which is placed transversely to the head, represents the hip-joint (*coxa*), and this is followed by a stem-joint (*stipes*), attached to it at a right angle, and corresponding to the thigh. On the outside of the latter is a separate piece, known as the scale (*squama*), which bears a

jointed organ, the *maxillary palpus*; and these two parts are regarded by zoologists as representing the shank and the tarsus. But besides these parts, the stem-joint bears on its inner side two masticating-plates, which are generally horny, variously-toothed, and assist in the division of the food. This, of course, is a very general description of the structure of the maxillæ, which present many varieties of formation in different members of the class Insecta.

Below or behind the maxillæ we find what is apparently a single organ—the lower lip, or *labium*—but which is really composed of a pair of organs united together in the middle line. The labium closes the mouth from below, and consists of several parts, which have received special names. Thus its basal part, which represents the two hinge-joints of the maxillæ amalgamated together, is known as the chin, or *mentum*; the part in front of this, which may be either horny or membranous in texture, is called the *ligula*, and corresponds to the stem-joints, and other parts of the maxillæ. It is not unfrequently cleft in the middle, and may also have one of the other portions of each half separate, forming distinct divisions, called *paraglossæ*. The labium also bears a pair of palpi (*labial palpi*).

The preceding statements are intended solely to give a general idea of the arrangement of the parts composing the mouth in ordinary insects, to clear the way for the descriptions of those modifications of structure which, it will be seen hereafter, are of great importance in the classification of these animals. They are of importance, also, in connection with the theoretical structure of the head, which, although apparently composed of one solid piece, must be regarded as really consisting of several segments, intimately united to one another. If we consider what these segments may be, and what is their theoretical number, interpreting the insect head by its homologies with the lower arthropods, we find that the following constituents may fairly be distinguished,—a segment bearing the eyes; a second segment, bearing the antennæ; and three more, of which the mandibles, maxillæ, and labium are appendages; the mandibles, which are solid, and bear no palpi, being regarded as representing only the basal joints (*coxæ*) of the members belonging to their segment. We thus get five segments in the head, which, taking eleven as the full number of segments in the abdomen, would give nineteen as the total number of segments in insects; but some anatomists are inclined to think that a second antenna-bearing segment must be imagined to exist, although in an undeveloped state, in order to bring the number of segments into accordance with that present in Crustacea. A remarkable and, so far as we know, perfectly exceptional, structure was described in 1879 by M. H. de Saussure, in a small Cockroach-like insect (*Hemimerus*), from the Gaboon, on the West coast of Africa. In this curious creature M. de Saussure finds a *second labium*, evidently composed of two halves, and having a pair of palpi, situated within the regular labium, and between it and the maxillæ. This, of course, would make the number of head-segments six, without reckoning the hypothetical second antennal segment, but unfortunately it is in the wrong place, and its occurrence is so exceptional that M. de Saussure is inclined to remove the creature possessing this remarkable character altogether from the class of Insects.

The modifications which these parts undergo, and which are characteristic of the orders, and other groups of insects, are very considerable, and will have to be fully described farther on; but a brief statement of the nature of the more important of them will not be out of place here, as placing the very curious phenomena in question before the reader in a connected form. The description given above indicates the general arrangement of the parts in the mouth of ordinary biting insects; and the differences presented by these are generally in matters of detail, such as the relative proportion of parts, &c. The first type which requires notice here is that presented by the Bees, in which the horny mandibles still retain their ordinary form and arrangement, and are, indeed, most efficient biting organs; whilst the rest of the organs of the mouth undergo important changes to fit them for the sucking-up of fluid nutriment. For this purpose the mentum, or basal part of the lower lip, acquires considerable power of movement, and the ligula, attached to it in front, becomes greatly elongated, at the same time that the maxillæ, which are also much elongated, acquire the form of thin blades, which embrace the sides of the ligula. By the union of these parts a sort of tube is formed, through which the food of the animal, consisting of the honey of flowers, can be easily sucked up, the mode of articulation of the parts enabling the whole composite organ to be pushed forward, or retracted beneath the head, at the will of the animal. Both labium and maxillæ are still provided with palpi.

In the Butterflies and Moths the change is apparently greater than in the Bees, although when the structure of the mouth in these insects is investigated the different parts are, if anything, more distinct. In Butterflies and Moths the upper lip and mandibles form three little plates, placed on the front of the head between the large eyes, but entirely concealed beneath the dense clothing of hairs with which that part is covered. Springing from the front of the head, beneath these rudimentary parts, we find a tapering organ, which is rolled up into a close spiral when in repose, but can be stretched out generally to a great length, and possesses considerable mobility. It is by means of this organ that the insects are enabled to suck up their food, which consists for the most part of the sweet juices of flowers; and, on investigation, it is found to consist of the maxillæ, which are produced into two thread-like organs, each bearing on its inner surface a half-tube, the junction of the latter forming the tubular organ through which the nectar passes. At their base these elongated maxillæ bear small palpi. The lower lip (or labium), like the labrum, is considerably reduced in size, and, indeed, may be nearly rudimentary; but, notwithstanding this reduction, it bears a pair of very large, usually three-jointed, palpi, which are in most cases densely clothed with hairs, and constitute those organs which may be easily observed in many Butterflies, projecting like a pair of stout horns in front of the head, and between which the spiral proboscis is rolled up when at rest.

In the other two principal types of haustellate, or sucking insects, all the parts of the mouth take part in the formation of the sucking organ, and in both the labium is converted into a sheath, within which are contained the representatives of the mandibles and maxillæ, reduced to a bristle-like condition. One great order of insects, distinguished at the first glance by the presence of only a single pair of perfect wings, the hind wings being represented by the little knobbed organs already described as halteres, is further characterised by having the labium converted into a sucker, often of a more or less fleshy texture, the upper cleft of which is closed by the elongated labrum, and within the tube thus formed are some bristle- or lancet-like organs, representing the mandibles and maxillæ, frequently accompanied by an unpaired piece of the same kind, which appears to spring from the labrum, and is called the *epipharynx*. The number of bristles or lancets contained in this sucking mouth may vary not only in different families or species, but even in the two sexes of the same species. The full number of five is scarcely found except in the females of blood-sucking species (such as Gnats and Breeze-flies); in the males of these and in most other forms there are only three bristles, two of which are proved to represent the maxillæ by the attachment to them of palpi near their base. It is then a matter of uncertainty whether the third bristle is to be regarded as the epipharynx, the mandibles being altogether wanting, or as composed of the two mandibular bristles, united into one. The extremity of the proboscis in this type is frequently enlarged into a double pad, like a pair of lips, one on each side of the aperture. This has been regarded by many anatomists as representing the labial palpi, by others as formed by the ligula and labial palpi united. It is well seen in the common House-fly and in the Bluebottle. The function of the bristle-like organs in the interior of the proboscis is to pierce the tissues containing the blood or vegetable juices upon which these insects feed.

The Bugs and their allies have another form of sucking mouths, to which the name of rostrum is given. As already stated, its sheath also consists of the metamorphosed labium; but here it forms a longer or shorter beak, tapering to a point and divided into three or four distinct joints, which may very well represent the joints of the labial palpi united along the middle line. The jointed organ thus produced, which is articulated to the lower surface, or the apex, of the head, has its sides bent round in such a manner that their edges come into close contact, or may be united together, forming a closed tube, except towards the base, where the edges of the first and sometimes of the second joint remain at some distance apart. The little gap thus produced is, however, closed by the more or less elongated labrum, which thus again completes the sucking-tube. Within this tube we find four long and fine bristles, representing the mandibles and maxillæ, and these, as in the Flies which were last described, can be pushed forth and retracted by the action of muscles attached to their bases. They serve, as, indeed, in one case is pretty well known, to pierce animal and vegetable tissues, and thus enable the juices contained in them to be readily sucked up. The maxillæ in these insects are quite destitute of palpi.

Hitherto we have been considering the characters presented by the mature or adult insect; but

in many cases the young present a very different structure. In all Arthropoda the skin, or rather the epidermis or outer layer of the skin, is a continuous formation, and as completely outside the growing part of the organism as the hair or nails of quadrupeds or the feathers of birds. Perhaps the best analogue is to be found in the epidermis of reptiles—in both cases the outer layer of the skin is continuous, and, when once formed, incapable of receiving any increase of size; hence, as the animal contained in it grows, there arises a necessity for the epidermis being thrown off from time to time. In insects this moulting (or *ecdysis*) regularly takes place; in some the skin is changed as often as twenty times; and in a great number the shedding of the skin is associated with a great change of form.

This, however, is not the case in all. A considerable number of insects, chiefly parasitic in their habits, are hatched from the egg in a form almost exactly resembling that of their parents.

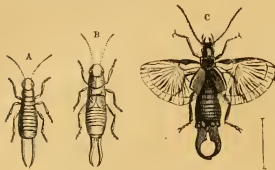


Fig. 7.—EARWIG IN ITS DEVELOPMENT.
A, Larva; B, Pupa; C, Imago.

Others, on making their first appearance in the world, more or less closely resemble their parents in shape, but nevertheless present certain differences, notably the absence of wings, which the latter possess (Fig. 7). In these instances the young insects in the course of growth change their skins several times, and at a certain period of their existence we find that behind the pronotum a pair of prominences not previously present have made their appearance. These are the cases containing the rudiments of the wings, which become fully developed after the last moulting. This condition of things may be observed in the Cockroaches and Crickets which frequent our

kitchens, in the Grasshoppers, whose shrill cry enlivens the meadows in summer, and in the whole tribe of Bugs.

In others, and indeed in the majority of insects, the change that takes place is much greater. The young insect creeps out of the egg in a form totally unlike that which it is ultimately to possess, and in some respects much more closely resembling that of the lower Annulosa, commonly known as Worms. Nearly all are soft, fleshy creatures, with the body divided into segments; some are entirely destitute of limbs and of any distinct head; others have no limbs, but are furnished with a horny head; others have jointed legs attached to the first three segments of the body; and others, again, in addition to these, possess a larger or smaller number of pairs of fleshy feet (prolegs) appended to some of those segments which represent the abdomen. In common parlance, the headless and footless forms are called *Maggots*; those with a head and no feet, and some of those which possess legs, are known as *Grubs*; and the forms with legs and prolegs are generally termed *Caterpillars*. The term *larvæ* is applied to all the different forms by naturalists, as also to the young insects above referred to, which resemble their parents in most respects except the entire absence of any trace of wings.

At the close of this so-called larval period of existence, however, there is a very great difference in the course of events in the two series of insects. As already stated, at the last change of skin, or, in some cases, at a somewhat earlier one, the larvæ which resemble their parents in general form acquire rudimentary wings, enclosed in cases which lie upon the sides of the body, behind the pronotum (see Fig. 7, B); but in other respects, as has been seen, the insect retains the same form as before, and continues to run about and feed like the larva. This goes on until the final moult, when the wings are freed from the case enclosing them, and speedily acquire their full size and development.

In the case of the more or less worm-like larvæ (*Caterpillars*, *Grubs*, *Maggots*, &c.), affairs go on very differently. When the larva has acquired its full growth and the last change of skin takes place, the result of this operation is the production of a creature wholly unlike the larva, and generally presenting no more than a distant resemblance to the perfect insect. Where this resemblance is closest, the product of this change of skin is a creature showing the division of the body into the three regions—head, thorax, and abdomen—characteristic of the perfect insect, but which was wholly wanting in the larva; the legs and antennæ, and the wings in an undeveloped condition are also distinguishable, but all these parts are enclosed in a skin, which closely covers

them, although they are already free and separate from the body. Beetles and Bees and Wasps furnish excellent examples of this condition, in which, although the parts of the future insects are rudely indicated, and often capable of moving a little under irritation, the general characteristic of the insect is a state of absolute repose.

In other instances (such as the Moths and Butterflies) we find that the parts of the mature insect exist in the same way, in an imperfectly developed state, but that they are closely applied to the body within their proper sheaths, and that a continuous case of a more or less horny texture envelops the whole, and renders all the parts incapable of motion, except that the abdomen can generally bend more or less. This outer case follows all the inequalities of the surface produced by the limbs, antennæ, wings, &c., which can thus be distinguished as easily as in the preceding forms. An insect in this condition is commonly denominated a *chrysalis*; it is, of necessity, incapable of moving about or taking nourishment.

As these insects generally pass a considerable time in this helpless and inactive condition, during which the parts of the perfect insects are being brought to maturity within them, the larvæ, before undergoing the change above described, usually select some suitable shelter for the purpose. Many burrow into the ground, and pass the interval of repose in a chamber which secures them from the attacks of enemies and the inclemency of the weather; others seek concealment in sheltered corners, or in the crevices of the bark of trees; others again content themselves with such protection as they can get by adhering closely to the stems or branches, or the under side of the leaves of the plants on which they feed; and not a few, even of those which take up their abode in sheltered situations, spin for themselves a silken cocoon, within which they pass their period of inactivity. In a very large proportion of two-winged flies, the transformation to the second stage takes place within the skin of the larva, which then dries and forms a protective covering for the insect during its period of repose.

The general name *pupa* is applied to insects in this inactive state, in allusion to the swathed appearance presented by the Moths and Butterflies at this period of their existence, *pupa* being the Latin term for an infant in swaddling cloths. But the same denomination has also been extended to the corresponding stage in the development of those insects which are active throughout their whole life; and thus we get the two categories of active and inactive pupæ, from each of which the insect emerges in the perfect, or, as it is called, the *imago* state. The whole series of changes, here referred to, constitute the *transformations* or *metamorphoses* of insects; and according as the insect is active or inactive in the pupa state, the metamorphosis is said to be imperfect or perfect. It will be seen hereafter that this distinction is of great systematic importance, and that, in tracing the possible genealogy of the class of insects, it is one of the principal matters to be considered. Here, however, we must confine ourselves to such a general exposition of the phenomena of metamorphosis as will suffice to render the subsequent chapters intelligible.

The internal anatomy of insects requires some notice, but it must be passed over very briefly. The idea of a segment, or somite, as it is now frequently termed, implies that of a repetitive succession of parts, that is to say, each somite is to be regarded with certain limitations, as of the same



Fig. 8.—LARVA (A), CHRYSALIS (B), AND IMAGO (C) OF *PAPILIO MACHAON*.

essential constitution as all the others forming the body. In the Annelids or Ringed Worms this theoretical condition is very nearly realised, that is to say, with the exception of a few modified segments, all the somites of the body are exactly equivalent, at least so far as regards the particular systems of organs which are related to the segmentation. These must necessarily be the organs produced from the outer germinal layer during the development of the embryo in the egg, namely, the integument, in which division into segments is so strongly marked, the central nervous system, and any organs directly connected with the skin. In perfect insects we find the division into segments sufficiently clear, but when we come to the interior the case is frequently very different. But in the larvæ of insects the conditions presented by the worms are almost exactly reproduced; and as,

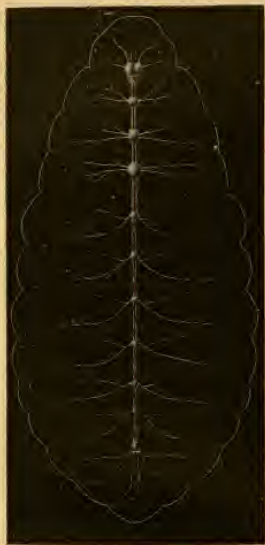


Fig. 9.—NERVOUS SYSTEM OF LARVA OF BEE.

notwithstanding the change of form, there is no denying the individual identity of the perfect Butterfly and its Caterpillar, for example, we must accept the peculiarities presented by the former as produced solely by the modification of parts present in the latter. This applies especially to the central nervous system, which often differs very greatly in the same insect at different stages of its existence.

Thus in most larvæ and in many perfect insects we find the central nervous system forming a more or less regular and uniform chain, extending from one end of the body to the other. In the head there are four nervous knots, or *ganglia* as they are called, two of them (which, however, are often united, although even then generally recognisable) situated above the œsophagus, and forming together what is frequently called the brain or the cerebral ganglion; and two, which are almost always amalgamated together, placed beneath the œsophagus. The upper and lower ganglia are united by short nervous cords (*commissures*) on each side, so that the œsophagus is surrounded by a sort of nervous collar or ring, more or less enlarged above and below. From the lower enlargement (that beneath the œsophagus) a pair of slender nervous cords, frequently united to form a single one, run backward into the thorax, and are continued throughout the length of the body, bearing in each segment, until they nearly reach the end of the abdomen, an enlargement or ganglion, which often shows traces of being composed of two halves (Fig. 9). In this way we get a chain of ganglia united by slender commissures, which may amount to eleven in number, exclusive of those in the head, that is to say, one in each segment of the thorax, and eight belonging to the abdomen. The maximum number of body-ganglia thus comes within

one of that of the fully developed body-segments. But from this uniform development of the central nervous system, the departures are exceedingly numerous and varied, in relation chiefly to the suppression or amalgamation of the segments in the perfect insects, the general tendency being to shorten the nervous chain, and thus confine the central masses more and more to the anterior part of the body, in accordance with the general direction in which specialisation takes place in this, and indeed in other classes of animals. Thus fusion of the ganglia of the mesothorax and metathorax, or of all the three thoracic ganglia into a single mass, may occur, while the abdominal ganglia still remain separate (Fig. 10); then the latter may unite into a mass which joins the thoracic mass, or the mass formed by the two hinder thoracic ganglia, to constitute a long single central nervous organ in which the original constitution out of separate ganglia is almost wholly obliterated. The nerves which in insects with a regular chain of ganglia issue from

the latter to run to the limbs and to the muscles and other organs of the abdomen, are then given off in a radiating fashion from this elongated nervous mass, those of the abdomen forming a brush-like tuft at the extremity of the consolidated chain.

With a few words upon these nerves we may quit this part of the subject. The upper ganglion of the head (*supraoesophageal* or *cerebral ganglion*) gives off in front a pair of nerves, which run to the antennæ, and above a nerve which goes to the simple eyes or ocelli when these are present, whilst on each side it is directly continued into the thick optic nerves that run to the large compound eyes. The lower, or *suboesophageal ganglion*, furnishes paired nerves which go to the upper lip and the paired organs of the mouth. The thoracic ganglia especially provide the nerves for the wings and legs; and the nerves of the abdomen govern the movements of that part, and especially the function of respiration.

The only organs of sense, to which we can with certainty assign a definite function are the *eyes* and *ocelli*. The latter are found as the sole organs of sight in many larvæ, when they are placed in groups on the sides of the head in the position afterwards occupied by the compound eyes. In perfect insects the ocelli are situated on the vertex or crown of the head, and they are then either two or three in number. They are small round organs, showing externally a convex transparent cornea, beneath which is the termination of a nervous branch, specially modified for the purpose of vision. The compound eyes are much larger, and usually very prominent organs situated on the sides of the head, the greater part of the surface of which they occupy in some insects. They may be regarded to a certain extent as composed of a multi-

tude of ocelli, which, in consequence of their being brought as close as possible together, assume a hexagonal form, and thus divide the surface of the composite organ into a number of facets of that shape. Their number is often exceedingly great, but it varies much in different insects. The smallest number recorded is 15 in the eye of a little Bee-parasite; the common House-fly has 4,000, and a species of Dragon-fly as many as 20,000 facets in its eye. Each facet is a small horny lens, usually flat on the outer surface and convex within. The centre of each lens is in contact with the base of a cone, which is frequently regarded as a crystalline body,



Fig. 10.—NERVOUS SYSTEM OF PERFECT BEE.

but which is really the outer termination of a nervous rod springing from the surface of the expanded end of the optic nerve. The nervous rods and conical bodies are enveloped by a layer of pigment separating them from their fellows. Thus, each of these thousands of facets may be regarded as possessing the structure of a distinct eye (Fig. 11).

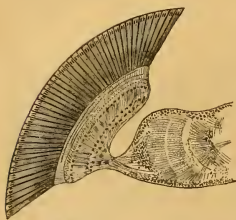


Fig. 11.—STRUCTURE OF EYE OF COCK-CHAFIN.

The antennæ appear to be the only other organs of sense possessed by insects, but it is exceedingly difficult to ascertain what sense it is their special function to serve, if, indeed, they may not have different offices to perform in different insects. They have been supposed to be organs of hearing and of smell, the former partly on observational grounds, and partly by analogy with the Crustacea; but while we may be certain that insects possess these senses, it is very difficult to point out their seat. The antennæ, however, in some cases, are certainly tactile organs. Special organs of hearing have been described in particular insects by various authors. In the common Grasshoppers they have been supposed to be placed in the sides of the abdomen,

in those of another family at the base of the anterior tibiae. The faculty of hearing has also been assigned to the hind wings of Beetles, and to the halteres of the two-winged flies. The possession of this sense by insects may perhaps safely be predicated from the fact that many of them have the faculty of producing sounds, generally by the friction of the wings, or of the legs against the wings, but in some cases by the agency of special organs.

The digestive organs (Fig. 12) commence by a pharynx attached to the organs of the mouth, and sometimes produced into free processes (*hypopharynx* and *epipharynx*), which especially in sucking insects may take part in the formation of the mouth. This narrows into a gullet or *œsophagus*, which runs through the anterior segments of the body, and becomes widened behind into a first stomach or *crop*. In many sucking insects, this dilatation of the *œsophagus* is not in the direct course of the alimentary canal, but placed on one side and united with the *œsophagus* by a narrow canal; it is then known as the *sucking stomach*. The abdominal part of the intestinal canal, presents great differences in different insects and groups of insects. In general in vegetable-feeders the intestine is comparatively simple in its character, but of considerable length and much convoluted; in carnivorous forms, on the other hand, it is shorter and runs more directly to the anal orifice, but is generally divided into several distinct sections, which have received special names. Thus, in many cases we find a *gizzard* (*proventriculus*) a short, more or less spherical, strongly muscular part, the inside of which is often furnished with several horny (chitinous) ridges; and beyond this a much longer and broader *stomach*, of delicate texture, with no chitinous lining, but commonly with a glandular layer, which often gives the surface of the stomach a villous appearance. Beyond this true stomach comes the intestine proper, which often presents a clear division into different regions; and at the point where the stomach and intestine join certain long, slender, blind tubes, known as the *Malpighian vessels*, usually open. These were at one time supposed to represent the liver, but they are now regarded as analogous to the kidneys in the higher animals. Besides these glandular organs we find in the anterior part of the body one or two pairs of salivary glands, which are also blind tubes, sometimes extending back within the abdomen, and not unfrequently possessing a reservoir in the neighbourhood of the mouth. Their secretion is discharged into the mouth during the mastication of the food.

Other glands not connected with the alimentary canal need only a passing notice. Odoriferous glands are not uncommon. They may be situated in various parts of the body, and have their orifices situated in the soft skin uniting the segments or at the joints of the limbs; or in the neighbourhood of the anal orifice, where they produce an acid secretion, which collects in a small vesicle, from which it is ejected as a means of defence. Silk glands are of common occurrence in the larvæ of insects. They consist of a pair of long, blind tubes, placed one on each side of the abdominal region, and communicating by a long duct with an orifice in the labium. The secretion of these glands has the property of hardening into a fine thread when exposed to the

air, and by means of it the larvæ are enabled to form protective coverings for themselves, and especially to prepare the cocoons in which so many of them pass their pupal period of existence.

A considerable portion of the interior of the body of an insect is occupied by a peculiar fatty substance called the *adipose body*, which is especially abundant in the full-grown larvæ, and consists of a yellowish, lobulated mass lining the walls of the body-cavity, and filling up the spaces between the viscera. It would appear to be a store of nutriment to be used up in the final maturation of the insects, as it often diminishes in volume in proportion as the reproductive organs are developed.

The *circulatory apparatus* of insects is sufficiently simple. It consists of a sort of vessel running along the dorsal part of the insect, and divided by constrictions into a series of chambers corresponding in number with the segments of the abdomen, and then continued forward in the form of a simple tubular vessel (*aorta*), through the thorax to the head. The chambered portion part of this *dorsal vessel* is attached to the walls of the abdomen by a series of triangular muscles, which spring in pairs from a broad base on each side of each chamber, becoming narrowed towards the place of their attachment to the skin of the abdomen. The blood within the dorsal vessel is driven forward by the successive contractions of the chambers until it is forced out from the anterior orifice of the aorta, whence it returns through the interspaces of the various organs (*lacunæ*) to the abdomen again. It then passes into the sort of sinus formed around the dorsal vessel by its muscles above described, and thence into the vessel itself through a series of valvular openings between the successive chambers, to be again driven out by the contractions of the organ. There are consequently neither arteries nor veins in the insect-body, and the circulation of the blood is strictly what is called *lacunar*.

Respiration is effected by means of an immense number of branched tubular organs called *tracheæ*, which communicate with the outer air by a series of peculiar apertures in the integument, known as the *stigmata*. The latter are situated on each side of the body, in the boundaries between the successive segments, but the head is altogether destitute of them, and the last pair of abdominal stigmata are frequently wanting. In the abdomen they are frequently placed in the membrane uniting the dorsal and ventral plates. In form the stigmata are sometimes round, when they are enclosed by a horny ring and furnished internally with bristles or hairs, converging towards the centre to prevent the entrance of injurious particles. In

other cases they constitute more or less elongated slits, and are then capable of being closed by a pair of lip-like parts, which also frequently bear spines or bristles, sometimes branched or pectinated. The closure of these stigmata is often effected by the agency of small chitinous pieces embedded in the membranous parts, which show a singular resemblance to the little bones found in the mammalian ear.

The *tracheæ*, into which these apertures admit the air, are tubular organs, branching through all parts of the body, and gradually diminishing in diameter towards their final ramifications. In this way they convey the air to all the organs, which they, at the same time, bind together and hold in position, thus, to a considerable extent, performing the double office of respiratory organs and



Fig. 12.—DIGESTIVE APPARATUS OF DYTICUS.

a, Oesophagus; c, Gizzard; d, Stomach; e, Small Intestine; f, Large Intestine.

suspensory ligaments. They are cylindrical membranous tubes, within which there is distinguishable a fine annulation, resembling a spiral chitinous thread, and this structure, which is continued into the very finest ramifications of the tracheæ, serves to give them sufficient elasticity to remain constantly open for the free ingress of the air. In general the wide tracheæ, which start directly from the stigmata, run inwards but a short distance, and then open into a longitudinal vessel of the same kind, which passes up the side of the abdomen, uniting all the main stems, and in this way a pair of lateral longitudinal tracheæ are produced, from which the smaller branches going to the various organs are given off; but occasionally the tracheæ from the stigmata run directly into the body. In many insects bladder-like dilatations of parts of the tracheal system occur, and these sometimes form very large air-sacs in the interior of the body; they are of membranous texture, and destitute of the spiral thread, although this makes its appearance again in the fine branches given off from them. Special modifications of this respiratory apparatus are, however, frequent in insects. In many cases, especially in air-breathing aquatic larvæ, the function of the stigmata of the sides of the body is suppressed, and the apertures themselves closed up, and respiration is effected solely by the agency of peculiarly modified stigmatic apertures at one or other extremity of the body. Again, many aquatic larvæ dwell constantly in the water, never coming to the surface to breathe, and, in these, while the structure of the tracheæ remains the same, we find, in place of the stigmata, peculiar organs, which have been called *tracheal gills*, by means of which the insects respire the air dissolved in the water they inhabit. These gills are usually leaf-like organs containing branched tracheæ, and they are sometimes appended to the sides of the abdominal segments, or confined to its posterior extremity.

Reproduction in insects takes place usually by eggs, which are deposited in suitable situations by the females. In many cases they are merely attached singly or in groups to plants or other objects, or deposited in the ground; in other instances they are inserted into the substance of the plant or animal on which the larvæ feed, by the agency of a peculiar organ (*ovipositor*) with which the female is endowed for this purpose; and sometimes the parent insects prepare nests of the most complicated character for the reception of their eggs and the subsequent rearing of their offspring. In some cases, however, the development of the eggs takes place within the body of the mother, and instead of eggs larvæ are then brought forth. A few insects even go further than this and retain the larvæ within their bodies until they have arrived at maturity, producing their young in the pupa state. These, however, can only be regarded as exceptions to the general rule, according to which the eggs are deposited before any development of the larvæ has taken place within them, and impregnated during their passage outward from the ovary through the oviduct, by contact with the male fertilising element, which has been stored in a special receptacle appended to the oviduct since the union of the sexes. The last-mentioned point is one of considerable importance in connection with the phenomenon of the production of insects from unfecundated eggs (*parthenogenesis*), and especially in the explanation of the constitution of certain societies of insects (such as Ants, Wasps, and Bees). In these it appears to be proved that the male individuals are produced from unfertilised eggs; and in a number of other insects eggs in the same condition have been known to produce larvæ, whilst of some no males have ever been seen, although the insects have been bred for several generations.

In one remarkable group of insects, including the Aphides, or Plant-lice, and some allied forms, reproduction takes place in a peculiar manner, which has been called *parthenogenesis*, but is really analogous to the so-called "alternation of generations," so frequent among animals much lower in the scale of organisation. In these insects, true male and female forms appear at certain intervals, and the latter produce true eggs; but between the hatching of these and the production of the next true males and females among their progeny several generations of insects succeed one another, which bring forth young by a process analogous to internal budding. The result of this process is sometimes a young living insect, sometimes a more or less egg-like body, and the history of the reproduction of these little creatures is thus rendered exceedingly complicated.

We have now only to indicate briefly the classification that will be adopted in the following pages. By going back over the preceding statements the reader will find that there are two sets of characters, by either of which the class of insects may be divided into two great sections, namely, the characters drawn from the structure of the mouth, that is, whether this is adapted for mastication or for sucking, by which we get the two groups of mandibulate and haustellate insects; and those

derived from the metamorphosis, by which the class may be divided into insects with a perfect metamorphosis, and those with an imperfect metamorphosis or no metamorphosis at all. For many years the former of these methods of division was the one adopted by almost all naturalists, and it has certain advantages in its favour, especially the practical one that, being founded exclusively upon the characters presented by the insects in the perfect state, the student has no occasion to trouble himself about the transformations which they have undergone in order to decide their place in the system. This advantage, however, is more apparent than real, for except in the case of a single so-called order of mandibulate insects the character of the metamorphosis forms part of that of the order; and, on the other hand, there are almost always ample structural distinctions by which the members of the orders can be separated, even without reference to their transformations. Further, taking into consideration the points that have been raised since the resuscitation of the doctrine of the evolution of organic forms by the works of Mr. Darwin and others, it must be admitted that from this point of view the nature of the metamorphosis is of great importance; and for these reasons we adopt a primary division of the class of insects in accordance therewith.

The only difficulty that presents itself more strongly from this point of view than from that of the structure of the mouth is how we are to deal with certain small groups of insects which undergo no metamorphosis at all. These creatures, which are generally of small size and low organisation, may be residues of groups formerly more numerous and abundant, in which case they ought probably to be kept distinct from the other existing orders of insects; or especially in the case of the parasitic forms, which are the most numerous, they may be degraded representatives of the orders to which they appear to be most nearly related. We shall adopt both these views for the different types of insects with no transformations, and arrange the orders as follows:—

I.—INSECTS WITH A PERFECT METAMORPHOSIS.

A. With biting mouths, the mandibles always distinct:—

- | | |
|--|-----------------|
| 1. Fore wings horny or leathery, forming a pair of sheaths (<i>elytra</i>) covering the abdomen and hind wings, and generally meeting in a straight line down the middle | 1. COLEOPTERA. |
| 2. All the wings membranous:— | |
| <i>a.</i> Veins in the wings few; prothorax united with the mesothorax | 2. HYMENOPTERA. |
| <i>b.</i> Veins in the wings numerous; prothorax free | 3. NEUROPTERA. |

B. With sucking mouths:—

- | | |
|---|-----------------|
| 1. Wings four, scaly; maxillæ forming a spiral proboscis | 4. LEPIDOPTERA. |
| 2. Wings not more than two:— | |
| <i>a.</i> Two wings; halteres; thoracic segments united; proboscis formed of the labium, enclosing bristles | 5. DIPTERA. |
| <i>b.</i> Wings none; thoracic segments distinct | 6. APHANIPTERA. |

II.—INSECTS WITH AN IMPERFECT METAMORPHOSIS OR WITH NONE AT ALL.

- | | |
|---|----------------|
| A. With sucking mouths; rostrum composed of the jointed labium enclosing bristles | 7. RHYNCHOTA. |
| B. With biting mouths, of which the parts are exposed; no organs of locomotion at the extremity of the abdomen | 8. ORTHOPTERA. |
| C. With biting mouths, the parts of which are usually very delicate, and concealed within the cavity of the mouth; no wings; no metamorphosis | 9. THYSANURA. |

By many entomologists the Aphaniptera, or Fleas, are united with the Diptera, or two-winged Flies. Of the insects with no metamorphosis, we have retained the order Thysanura, the members of which have sometimes been united with the Orthoptera; but of the parasitic forms, the true Lice are referred to the Rhynchota, and the Bird-lice (Mallophaga) to the Orthoptera. The Bee parasites, forming the order Strepsiptera of many writers, are placed among the Coleoptera. Some years ago Prof. Westwood founded a distinct order (Aelrioptera) for a small insect parasitic on the Canadian Beaver. This has also been shown to belong to Coleoptera. The order Diploglossata, proposed by M. de Saussure, in 1879, for a small African insect resembling a Cockroach, but presenting a second labium, may be referred to the Orthoptera.

W. S. DALLAS.

CHAPTER II.

ORDER COLEOPTERA—CARNIVOROUS BEETLES.

Definition of the Order—Functions of the Coleoptera in Nature—Total Number of Existing Species—External Structure—Metamorphosis and Early Stages—Instincts—Voice-organs and Organs of Hearing—Hidden Nature of the Haunts of the Majority of the Species of Coleoptera—Nocturnal Habits—Attracted by Light—The Number and Variety of Species swept down by Floods in River-valleys—Fossil Beetles—Section PENTANERA, Beetles with Five-jointed Tarsi—Tribe ADEPHAGA, or Predaceous Beetles—Family CICINDELIDÆ, or Tiger Beetles—Family CARABIDÆ, Carnivorous Ground Beetles.

THE order Coleoptera embraces that large section of the insect tribes known under the name of Beetles, in which the anterior, or upper, pair of wings are converted into horny covers, or sheaths, meeting in repose in a straight suture down the back, and protecting the posterior, or membranous pair of wings, which, when not in use, lie folded beneath them. Further distinguishing characters are supplied by the mandibulate mouth, adapted for masticating food, and the complete metamorphosis which the individual insects undergo in their growth from the larva to the adult stage. These three important characters, in combination, effectively distinguish all members of the order from the Hemiptera and Orthoptera, which have a superficial resemblance to Beetles in the anterior wings being also more or less indurated, and serving as protecting covers for the membranous wings. Cockroaches, mistaken for "Blackbeetles" by the ignorant, have scarcely anything in common with the true Beetles, and belong to the order Orthoptera. On the other hand, the Lady-bird, the Turnip-fly, and the Glowworm, in which similar superficial observation is apt to fail to recognise the likeness to Beetles, truly belong to this order. The wingless female of the Common Glowworm, and some few other apterous species, are only cases of arrested or retrograde development.

The compact form and solid integuments which are the rule in Coleoptera adapt them for a far greater diversity of modes of life than is enjoyed by other orders of insects, and especially for plying their vocations in hidden situations; their relative strength and protective armour enabling them to gnaw or force their way out of the interior places where they have passed their larva and pupa stages. They may be said to perform the function in Nature of universal scavengers, chiefly with regard to the smaller quantities of animal and vegetable matter neglected by the larger animals, but not always, their small size and very varied forms and instincts enabling them to attack, by methods impossible to other animals, and to clear from the earth's surface, the carcasses even of large quadrupeds and the dead trunks of the largest forest trees. Different groups are organised respectively for terrestrial and aquatic life, and for every shade of variety in each; for living in or feeding on vegetable substances, from the smallest cryptogams, to the root, bark, wood, fruit, and seed of the highest forms of vegetation; and for disposing of excrementitious as well as dead animal substances. All forms of locomotion are displayed; many are specially adapted for burrowing, and for such curious operations as sawing branches or drilling holes in solid wood. There are predaceous groups—terrestrial, arboreal, and aquatic—and groups parasitic on the living bodies of other insects; there are separate sets of alpine, forest, field, and desert forms, in almost every climate, and there is a special Beetle fauna inhabiting the remotest recesses of limestone caverns. In size, Beetles present all gradations, from a length of one-thirtieth of an inch to half a foot.

Such being the wide range in modes of existence, and the consequent diversity of adapted forms, it is not to be wondered at that the number of species of Coleoptera is very large. No fewer, indeed, than 80,000 species have been already described, and all our larger collections contain many that are still unpublished. It is estimated by Professor Westwood that the total number existing in Nature is not less than 100,000; this one order of insects is therefore nearly ten times as numerous as the whole class of Birds, and more than double the whole of the Vertebrata. The classification of the order has been the object of study of many able entomologists since the days of Latreille, who applied the natural system, founded by Jussieu in Botany, to the Insecta. The more recent systematists have grouped the host of forms under seventy-five natural families. In the present work, whilst adopting these well-defined groups, we have, for convenience, restored the larger divisions of Latreille, founded chiefly on the number of joints in the tarsi, or feet, and the form of the antennæ, parts of the mouth, and the habits.

The illustration on p. 281 will suffice to explain the divisions of the body of a Coleopterous insect, and the parts of its upper, or dorsal, surface. The insect is represented as divided into four parts, viz., (1) the head; (2) the pro-thorax (bearing the anterior pair of legs); (3) the meso- and metathorax (bearing the intermediate and posterior legs, the wing-covers, and the wings); and (4) the abdomen. This last in the living insect is, however, usually closely attached to the metathorax, forming with it and the mesothorax the so-called "hind body." The mouth consists of a labrum, or upper lip; a mentum, or chin; a lower lip, immediately adjoining the mentum, and two pairs of jaws, viz., the upper, or mandibles, and the lower, or maxillæ; the latter and the labium bearing each a pair of small-jointed appendages called palpi. All these parts are subject to a wide range of modification, which furnishes not only a guide to the food and habits of the insects, but to their classification, the form of the different parts of the mouth being amongst the most constant characters of the genera and families. Throughout all the modifications, however, it is to be noted that the labium, or lower lip, never assumes the form it does in the order Orthoptera, where it shows a division into two lobes, or blades, indicating its fundamental condition, in the lower annulose types, as a third pair of mouth-appendages, bearing the labial palpi on the sides. In Coleoptera, the lower part of the labium is much contracted in size, and the upper part, forming the ligula, or tongue, is an undivided horny or coriaceous plate. This difference is important, as constituting one of the chief signs of the higher specialisation of the Coleopterous order. Besides the mouth, the under-surface of the three segments of the thorax requires the attention of the student. Each segment beneath is normally divided into five parts, or plates, separated from each other by fine sutures, the middle plate protruding a narrow lobe between the articulating cavities, or sockets, of each pair of legs, and the side pieces (two on each side, called episternum and epimeron) being of various shapes according to the genera. The form of these breast-plates, or sternums, especially the various shapes of the processes between the haunches of the legs and the extent to which they take part in forming the rim of the haunch-sockets, constitute most trustworthy guides in ascertaining the natural relationship of the genera and families. The abdomen is composed of a series of rings, or segments, each having its dorsal and its ventral plate, or segment, the spiracles, or breathing-holes, being on or near the points of junction of the two plates. The legs are composed of (1) a haunch, which articulates with the body; (2) a small narrow appendage, on the inner side at its apex, called the trochanter; (3) the femur, or thigh; (4) the tibia, or shank; and, lastly (5), the tarsi, or foot, consisting of a number of joints, differing according to the great primary divisions of the order, and bearing a pair of claws at their tips.

With regard to the stages through which Beetles, like all true insects, have to pass before reaching the winged adult state, we have already said that their development is by complete metamorphosis, that is, the intermediate stage between the active, feeding, larva and the adult, variously called in the different orders, pupa, nymph, or chrysalis, is a period of quiescence, the insect being encased, trunk and limbs, in a membranous or horny integument, and having time and repose sufficient for the elaboration of the great change taking place in nearly all its parts. The metamorphosis, however, is not so complete as in the Lepidoptera (Butterflies and Moths), the swaddling-cloth of the pupa not forming a simple case, but separately covering body and limbs. The larva varies very greatly in form in the different families; it is generally elongated, clothed with a tough skin, and furnished with six feet, in which case it has often a tolerably close resemblance to the perfect insect, minus the wings; but in some large groups it is a footless maggot, and, again, in a few parasitic genera it is an active hexapod in one stage of its growth and a maggot in another. In all its forms, however, it has a distinct head, and thus may be distinguished from the often similar larvae of Dipterous insects. Viewing the order generally, it may be said that the larva is less unlike the adult and the metamorphosis less complete, than in the Hymenoptera and Lepidoptera, and that the Coleoptera must therefore rank as a less perfect or specialised type than either of those orders of insects.

Amidst all their great diversity of forms and habits, the Coleoptera offer no example of those wonderful social and architectural instincts which excite our admiration in Bees, Wasps, and Ants of the order Hymenoptera, and of White Ants in the Orthoptera. Neither are there any instances of a third, or neuter class of individuals, such as we see in the social species of the above-named orders. No clear case even of co-operation among the individuals of a species is known; the nearest approach

to it, namely, that of the Burying-beetles, many of which are seen engaged together in interring carcasses of small mammals, being only the accidental assembly of a number of individuals, generally of different species, each intent on providing independently for its own young, just as a crowd of Geotrupes will work together at a recent cow-dropping, or a swarm of Bark-beetles be attracted to a newly-felled tree. Without reaching this high stage of development of insect intelligence, however, Beetles display instinctive qualities of great perfection and diversity. This is manifested in the arts resorted to by them in entrapping their prey; as in the larva of the Tiger-beetle, which stations itself in a hole it excavates in a sandy bank, and traps incautious flies who tread on the broad head of the insect, that closes the orifice of the hole; and also in the many contrivances adopted by the mother insects for securing a supply of pabulum to their offspring, as in the dung-feeding scarabæi, and the Sitaris, whose habits will be detailed farther on. The extensive prevalence of voice-organs in the male insects of the order is a proof of a considerable amount of understanding between the sexes, the sounds emitted being the calls of the insect to its mate. An excellent *résumé* of this subject is given by Mr. Darwin ("Descent of Man," Vol. I., pp. 378-384). The sounds produced are a kind of stridulation, similar to, but less shrill, than that produced by Crickets and Grasshoppers. Although very diverse in form and situation, the stridulating organs are all on a similar principle, which is that of fiddle and bow, two contiguous parts of the body being mutually adapted for being drawn or rubbed the one across the other. In the great family of Longicorns, the sound is produced by the friction of the hind rim of the prothorax over a finely-ribbed prominence on the mesothorax beneath. These ribs are microscopic, and M. Landois counted as many as 238 on the rasp of *Cerambyx heros*, a common European Longicorn. Many species of this family will stridulate vehemently from alarm, when held tightly between the finger and thumb. The sound is faint in small species, but in the great Harlequin-beetle of tropical America stridulation is so loud that it may be heard at some distance before the insect is seen. In the Necrophori, or Burying-beetles, the organ is situated on the upper surface of the fifth abdominal segment, and consists of two narrow finely-scored bands, which are rubbed by a ridge lying under the apical edge of the shortened wing-covers. In Geotrupes, again, it is the haunches of the posterior legs which bear the fiddle, in the form of a raised band, crossed by fine ribs, across which the hind margin of the third abdominal segment is drawn by a short motion backwards and forwards. These voice-organs exist in both males and females in our common *Geotrupes stercorarius*, as in some other species of Beetles, and the stridulation, therefore, serves both sexes as a mutual call. It appears also to be used in some large species of Stag-beetles as a note of anger or defiance. Some Beetles, on the other hand, produce a sound evidently intended for communication with others of the same species, not by stridulation, but by ticking or rapping, as in the well-known case of the Anobium, or death-tick, which burrows narrow galleries in the wood of old furniture. When performing, the insect fixes itself firmly on its six legs, and then taps against the wood by a series of hammering movements of the whole body, the hard mandibles at each blow coming in contact with the wood. It is easy to induce the Anobium to tick, by imitating the sound with the finger-nail on the wood, when it raps in response.

The existence of sound-organs so curiously elaborated in so many Beetles belonging to different families, implies a corresponding development of the sense of hearing. But although much observation and study have been devoted to this subject, physiologists are not yet in accord as to the situation of the hearing apparatus. The preponderance of opinion seems to be in favour of the antennæ being the ears in the insect class, although the evidence is not yet clear as to the existence of a tympanum at their base. A fine surface sculpture in many of the joints of these organs, which presents itself generally as minute pores, densely pubescent, is supposed to indicate an apparatus for the reception and transmission of acoustic vibrations. In this point of view the minute structure of the antennæ becomes a very interesting study, deserving of more attention than has yet been paid to it, especially as it is constant throughout the minor groups, and offers in those families where it has been attended to excellent characters for natural classification. It is found, on investigation, that the finely-sculptured, pubescent, or porous spaces are not often spread equally over the whole of the organs, but are localised on some few of the joints, and in different situations, according to the species, genera, or groups of genera. According to the celebrated anatomist Landois, the organ of hearing in Stag-beetles is confined to small pits, situated one on each side of the terminal plate of the club. The

sensitive surfaces of the thin plates forming the apical joints of the antennæ of the true Lamellicornia are shown to be of high importance to the economy of the insects, by the care Nature has taken in protecting them. Pits, crowded with sensitive pores, exist very generally throughout the great family Buprestidae. In Longicorns, where the stridulating organs are so well developed, and the sense of hearing ought to be acute in correspondence, the antennæ are often beautifully sculptured with parallel striae, but this is chiefly in the male sex, and it is believed that it is the length rather than the texture of the antennæ which in this family adapts them as effective organs of hearing. The Adephagous, or carnivorous families, present a minute porosity and fine pubescence on most of the antennal joints, leaving always a small number of smooth basal ones, the number of smooth joints being of remarkable uniformity in each sub-family or group of sub-families.

A very large proportion of the species of Coleoptera, especially in hot countries, come forth from their hidden feeding-places only after sunset, and a large number pass their whole lives in concealment. Owing to this circumstance, it is only a small minority of the Beetle fauna of any district which meets the eye of the inexperienced naturalist in his mid-day rambles throughout the summer months. This minority consists of such diurnal species as are found on foliage and flowers, or running about over banks and pathways, or on the wing; such species are most abundant in the spring or early summer, the first heats of July sending back to their hiding-places all except those which have by that time provided for the continuance of their species and died. But the bulk of the species are never seen in the open in broad daylight; they have to be sought for in their hidden haunts, amongst vegetable *débris* and garbage of all descriptions, about the roots of herbage, under stones, in and under bark, and in decaying timber, in water rich in aquatic vegetation, in ants' and wasps' nests, in the soil by digging, in the interior of stems of plants, in moss, in manure heaps, under boulders, in the recesses of caverns, and in many other situations where it would seem but little likely they should occur. In tropical countries a large number of species are never seen except on the rare occasions when they fly abroad in sultry evenings at the beginning of the rainy season, at which time they may be attracted by a light placed in front of a sheet or a whitewashed wall. Sometimes their flight is continued far into the night, and if a sudden shower occurs, chilling the air, whilst they are traversing a river or lake, they are cast down by myriads into the water, their half-drowned bodies being cast up by ripples on to the beaches, where a fine harvest of rare species, never otherwise seen, may be gathered by the collector. A similar phenomenon occurs also when sudden floods inundate a river valley, in temperate as well as hot countries. If this happens in the spring, and in a district generally favourable to insect life, the waters sweep down nearly the whole Beetle population from the upper valleys to the lower plains, where, amongst the trees and bushes, every stem and leaf may be seen covered with a miscellaneous crowd, endeavouring to escape from the deluge. The floating *débris* on the water will also swarm with other half-drowned crowds, and when the flood subsides, a little industrious collecting from the sediment stranded on banks, or deposited in trees and hedges, will yield a larger number of species than could be found by ordinary search during a whole summer in the same district.

Before concluding these introductory remarks on the order, a few words may be said regarding fossil Coleoptera. When the highly-specialised structure of Beetles and the absence in the existing creation of connecting links between them and other orders of insects are considered, both of which require long periods of time to bring about, it is not a matter of surprise to find that the type is of great geological antiquity. As far as our present knowledge goes, however, Beetles were preceded in time by the more lowly-organised orders Neuroptera and Orthoptera. The earliest insects known have been found in rocks of the Devonian period in North America, and belong to the Neuroptera. Coleoptera first make their appearance in the subsequent Carboniferous Age; but they seem to be of very rare occurrence, as only two species have been detected, one a Weevil (*Curculioides antiochii*), and the other a Lamellicorn, resembling the existing genus *Trox*, and named *Troxites germari*. That these earliest of all known forms should belong to two of the most highly organised families of the order is a matter for legitimate surprise; and the fact is only to be explained on the hypothesis, in which all modern biologists are agreed, that our oldest fossiliferous strata are far more recent in date than the origin of life, or even the commencement of differentiation of the orders in the lower classes of the animal kingdom. Later on, in the Secondary

period, Coleoptera are found in the Lias in some abundance, and of such definite forms that they have been referred without hesitation to many of the modern families—Carabide, Gyrinide, Hydrophilide, Scarabæide, and so forth; in the lower marls of the Lias in the Swiss Alps no fewer than thirty-three species of Buprestide have been found, two of them supposed to belong to genera which still exist. The resemblance to existing genera is carried still farther in the Oolite and in the Upper Eocene; and in the Lower Miocene it becomes so close that the numerous Beetle fossils found in beds of this formation in Central Europe belong for the most part to genera which still inhabit the same countries.

SECTION I.—PENTAMERA. BEETLES WITH FIVE-JOINTED TARSI.

TRIBE ADEPHAGA.

The first tribe of the order Coleoptera, or the Adephaga, is distinguished from all others by an organisation specially adapted to carnivorous and predaceous habits. The general form of body is slender, the three chief segments—head, prothorax, and hinder-body—having free play, and the limbs are constructed for rapid locomotion. All have five joints to the tarsi; the hamches of the first two pair of legs are rounded, and move in rounded sockets; the abdomen beneath is composed of six or seven segments, of which the first three are soldered together; and the antennæ are always slender and light, being thread-shaped, or tapering to the apex, composed of eleven sub-cylindrical joints, and never club-shaped at the tip. But the chief points of distinction from other tribes reside in the parts of their mouth, as in the analogous case of the dentition-characters of the order Carnivora in the Mammalia. The maxillæ are horny and generally hooked, forming a second pair of instruments for cutting and tearing, and their outer lobes are transformed into an additional or third pair of palpi. The mentum, or chin, is always well developed, and of definite form and outline, being horny throughout, with a free upper margin, excised in the middle, and often armed in the centre of the angular excision with a tooth. From its upper inner edge rises the ligula, or tongue, generally an oblong and angular horny plate, flanked by the adherent slender paraglosse, and fronted at its base by the labial palpi. The Adephaga are distinguished generally from all other sections of the order by the sharply-defined form of all the parts of the mouth, and the ease with which they may be examined. Within the limits sketched out by the above characters, they are subject, as well as other parts of the structure of the insect, to great modification, in correspondence with the greatly-diversified modes of life of the countless members of the group. The section is composed of four families, viz., Cicindelide, Carabide, Dyticide, and Gyrinide, which are re-combined by many authors under two sub-sections according to their mode of life; one named Geodephaga, or Land-beetles, comprising the first two families; the other Hydradephaga, or Water-beetles, including the last two.

FAMILY CICINDELIDE, OR TIGER-BEETLES.

Cicindelide are the elegantly-formed and nimble insects known popularly as "Tiger-beetles." The raptorial type of structure is in them carried to a high degree of perfection. Their eyes are large and prominent, and all their movements show extreme wariness. Most of them make ready use of their wings in flying, besides being endowed with remarkable speed of foot, and their mouths are well adapted for seizing and retaining their prey, their mandibles, or upper jaws, being long, and furnished with numerous sharp teeth, and their maxillæ and palpi studded with rigid bristles, which retain from the sides and beneath anything transfixed by the mandibles. With regard to other organs of the month, they differ from Carabide in the greatly diminished size of the lower lip, which does not project beyond the edge of the mentum, and in the basal support of the labial palpi being articulated, forming a fourth joint. These lip-palpi, in fact, from their length, and, in many cases, the width of their joints, added to the rows of bristles with which they are furnished, supply the place of the mentum, in closing the orifice of the mouth from below, thus furnishing one of those cases of compensation which are so frequently observed in insect structure and functions. The last feature in the mouth-structure which we need notice is the articulated horny hook at the apex of the maxillæ, which distinguishes nearly the whole of the family from all other members of the section, in which the hook or point is simply the terminal portion of the blade.

The number of species of Tiger-beetles at present known is not much less than 1,000, classified under five sub-families and about forty genera. They are found in all the warmer parts of the earth, with the exception of oceanic islands; and some species range as far north as Lapland. The majority

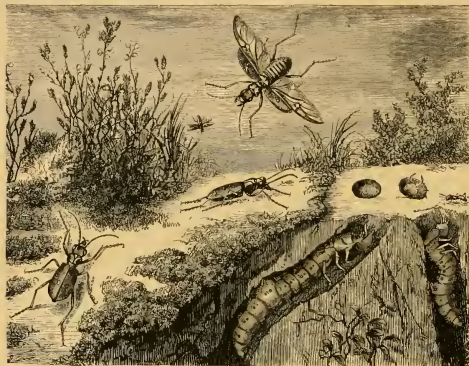


COLEOPTERA ESCAPING FROM A RIVER-FLOOD.

frequent sunny banks and bare places having a light soil, such as sandy sea-shores, banks of rivers, and pathways on heaths and in woods. Here they hunt their prey, and pass through their earlier stages, the larvæ, soon after being hatched in the warm soil, burrowing deep cylindrical galleries more or less vertical, in which they conceal themselves, their broad heads, armed with long mandibles, closing the orifice and entrapping any unwary insect which falls in their way. Four species of true Cicindelæ are found in the British Islands, the commonest of which (*Cicindela campestris*), abundant in the southern counties, may be taken as a fair sample of the whole family. It is of a beautiful light green colour, with opaque shagreened surface, the underside and legs having a brilliant coppery and golden lustre. The elytra bear traces, in a number of small, whitish spots, of the characteristic markings of the family, which occur in nearly the same position, but endlessly varied, in hundreds of its species, and most frequently form a flexuous band across the middle, with crescent-shaped spots at

the shoulders and the apex.

The bands are represented in *Cicindela campestris* by detached spots only, which lie in the position of the ends, or angles, of the bands and "lunules," as the crescent-shaped markings are termed; but in Central and South-Eastern Europe varieties of the English species occur in which the middle spots are linked together by a white band across each wing-case, showing that these different patterns are but modifications of one type. The other British species are *Cicindela sylvatica*, found only on heaths in the southern counties; *Cicindela maritima*, occurring



CICINDELA CAMPESTRIS AND LARVÆ.

on sandy sea-shores in the east and south, and as a distinct local variety in Lancashire; and *Cicindela germanica*, which has been met with only in a few localities in the south of England.

The genus *Cicindela* comprises more than half the species of the entire family. With the exception that some of the species found on sandy shores in tropical and sub-tropical regions have the legs developed to an extraordinary degree of length and tenuity, and that in others the white markings are so greatly extended as to cover the whole surface of the elytra, there is no very wide difference either in form or colouring between them and the English species. The largest and handsomest are the richly-coloured *Cicindela chinensis*, abundant in rice-fields in China and Japan, and *Cicindela octoguttata*, an inch in length, a native of Assam. Some of the smaller species at times occur in immense numbers on pathways in hot countries, rising like swarms of flies as one walks along the streets of a tropical village.

The other genera recede more in habits than in form from the typical *Cicindela*. Thus the *Odontochile*, slender, dark-bronzed forms, are found only in the shade of tropical forests; the *Oxygonia*, most resplendent in colouring, fly and run about mossy boulders in mountain-torrents of the Andes; the *Hiresia*, of tropical America, and the *Therates*, *Collyrides*, and *Tricandyle*, of tropical Asia and the islands of the Malay Archipelago—in all which the prominence of the eyes is carried to an extreme—are arboreal insects, running and flying after their prey along the branches and over the trunks of trees in the virgin forests. The *Phæoxantha*, a species of which (*Phæoxantha klugii*) is represented in our engraving, are remarkable in being nocturnal insects. They make very little use

of their wings, but are extremely swift runners, coursing in serpentine motion over the smooth sand-banks of rivers in South America; the species are all of pallid, clayey-white hues, and the burrows of their larvæ reach a depth of two feet in the sand, the perfect insects concealing themselves during the day in similar burrows. The antennæ are longer and thinner in these interesting insects than in the typical sun-loving genera of the family. In this and other respects they resemble the brilliant metallic-coloured *Tetrache*, some of which also seek their prey at night, but they do not abstract themselves so completely from the daylight as do their pallid relatives, the *Phæoxanthæ*. The genus *Tetrache* occurs in the Mediterranean region, in Australia, and in tropical and temperate America. The only other Tiger-beetle forms we need mention are the *Manticore* and their allies, the giants of the family. They are distinguished by their uniform black colour and the absence of wings, and are found in the extensive sandy districts of South Africa (where the largest, the true *Manticore*, resembling huge black spiders, occur), in California (the genus *Omus*), and at the eastern foot of the Rocky Mountains, which is the home of the *Amblychila cylindricornis*, an insect formerly of extreme rarity, but which has recently been taken by American entomologists in great abundance under wet hides, laid as traps on the ground over-night. An isolated form of this sub-family, the *Agrilus fallaciosus*, is found at Sandy Point, in the Strait of Magellan.

FAMILY CARABIDÆ, OR CARNIVOROUS GROUND-BEETLES.

The second family (*Carabidæ*) is distinguished from the Tiger-beetles by the general form, or *facies*, of its species, and by slight modifications, difficult to make clear by description, rather than by definite structural characters. All the apparent peculiarities of the external anatomy, such as the simple anterior tibiæ, many-toothed mandibles, atrophied labium, jointed apex of maxillæ, &c., are repeated in some few of the genera of *Carabidæ*. These genera belong to the first, or less numerous, division. In the great bulk of the family, forming the second division, the notch on the inner edge of the anterior tibiæ and the sensitive pubescent surface of the basal joints of the antennæ, of which only two or three joints remain polished, supply effective points of distinction. Bearing this in mind, the student will never be in a difficulty in assigning a doubtful species to its right family. In *Carabidæ*, the style of coloration and markings of the Tiger-beetle is nowhere seen; nor do the mandibles, even when long and toothed, as they are in some few genera, assume the slender curved form and sharp dentition characteristic of that family; other minor differences are the narrower and simpler upper lip and less prominent eyes.

Although the habits of the *Carabidæ* are very varied, there is not much diversity in the forms assumed in their early stages, or in their transformations. With few exceptions, the larvæ conform to a simple type, having elongated bodies, tapering behind, furnished with six legs and a horny plate on each of the thirteen segments, the thoracic segments being more horny, but not much differing in shape from the rest. The head is of oval form, and the opening of the mouth small, showing that their food must be taken in small and semi-fluid particles. The upper jaws, like those of the perfect insects, are much smaller than in the Tiger-beetles; and the eyes are six in number on each side, disposed in two rows immediately below the short antennæ. They inhabit generally the same situations as the perfect insects; and both are often seen together in the sheltered and dark places where they seek their prey, such as under stones or logs of wood, about the roots of herbage, in moss, among dead leaves, or under loose bark of trees. Some species have the anomalous habit of feeding on vegetable substances; at least, this is indubitably the case with the larva and perfect insect of *Zabrus gibbus*, a dark bronzed species of the *Pterostichini* sub-family, of oblong, heavy build, found in great abundance in Central Europe, and less commonly in England. It frequents wheat-fields, and devours the grain, proving in some years very destructive in France and Germany. Vegetable-feeding propensities have also been ascribed in other genera, such as *Amara* ("San-beetles," applied to *Zabrus*), *Ditonus*, and some species of *Harpalus*.

The number of species of *Carabidæ* at present known is not less than 10,000; and they appear



PHÆOXANTHA KLUGII.

to occur everywhere on the land-surface of the earth where life exists at all—in the most desert places of the tropics, in the Arctic regions, up to the line of perpetual snow on mountains, and in the deepest recesses of limestone caverns (*Anophthalmi* and others), where, for countless generations deprived of the merest glimmer of daylight, a numerous tribe are found completely blind, and with all traces of eyes obliterated. They are well represented on the remotest oceanic islands, generally in species and genera curiously modified from all known forms of the nearest continents. Some genera of very minute species (*Scotodipnus* and *Anillus*) have been discovered underneath huge secular boulders, embedded many feet deep in the earth, and requiring crowbars and the strong arms of labouring men to overturn in order that they may be reached. In temperate latitudes the great majority of the species are ground-beetles, at most hiding themselves in moss or under stones;



CARABUS AENEUS.

many genera, however (*Scaritinae*), are diggers, being furnished with strong, palmated fore-shanks (analogous to those of the Mole-cricket) to suit their fossorial habits, and thus being enabled to burrow to considerable depths in the soil to get at their special prey, the small insects which infest the roots of shrubs. But in tropical countries, more especially in the plains, where the functions of insect scavengers, on and immediately under the soil, are almost monopolised by the ubiquitous ants, ground Carabidae are much less numerous, at least, in individuals. In these climates the majority of the native species of the family live on trees. These arboreal species are more varied in their forms, offer more peculiarities of structure, and are usually more beautifully-coloured and marked than the ground species; they exhibit also interesting modifications of structure suitable to their habits, the tarsi, or jointed feet, being often lobed, and their claws elegantly toothed, to enable them to cling to the edges or surface of leaves. Those which live under the rotting bark of huge forest trees have, instead of the adapted feet, flattened bodies, enabling them to penetrate narrow crevices, and the parts of the mouth are in some cases also prolonged and flattened, the better to enable them to seize their prey in such situations.

Like most other families of Coleoptera, but perhaps in greater degree than any other, the Carabidae

readily assume the dormant condition; this enables them to withstand extremes of temperature, and to flourish in a great diversity of climates and situations. In cold climates their favourite winter retreat is in beds of moss; and they may be found in numbers in England in such situations, on sloping banks and at the foot of trees, where moisture does not accumulate, throughout the winter. On the other hand, in arid, sandy tracts in Australia and Africa, where so many fine species occur, they no doubt pass the great heats of the dry season in burrows or sheltered places at the roots of brushwood, for they are quite as sensitive to heat as they are to cold. Even in cool countries like Britain they are very rarely seen abroad in hot and dry summer weather; and in the tropics, during the many months of the dry season, they all disappear, to come forth only with the return of the rains.

The means of defence from their enemies possessed by the Carabide are less varied than in most other families of Beetles. They have generally great speed of foot, and many of them take wing readily enough, or conceal themselves rapidly among herbage, but cases of protective disguises or mimicry are unknown or very doubtful; this applies even to the simplest form of disguise, assimilation of form and colour to the material of their surroundings. This deficiency seems to be made good by the faculty which they possess of secreting an acrid, or fœtid, liquid from the anus, which is effected by means of special glands. The liquid is ejected sometimes with force when the insect is handled; and in one well-known group—the *Brachini*—the secretion is volatilised, and issues forth as a little cloud of smoke. The *Brachinus crepitans*, a common insect under stones in the South of England, has been observed to discharge its singular weapon when pursued by an insect enemy; and it derives from this habit its popular name of "Artillery-beetle." A slight sound is sometimes audible when one of the Beetles fires its mimic gun whilst held in the fingers. The explosion and its effects are, however, very much stronger in some of the large exotic species, such as the South American *Pherosophus complanatus*, which, when caught, will often crepitate quite loudly several times in succession, and cause a burning sensation in the fingers, which are stained brown where the vapour has touched them.

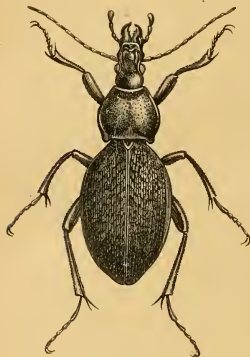
The vast host of specific forms of which the family Carabide is composed group themselves naturally under two divisions, founded on an important difference in the framework of the sternum, or breast. The difference is this: in one set of forms, constituting the first division, the hindmost of the three side-plates of the middle thorax (mesothoracic epimera) reach inwardly to the sockets of the haunches of the middle pair of legs; in the other set, forming the second division, they stop short, so that the orbit of the sockets is tightly closed by the meeting of the central-plates of the middle and hind thorax. Although the physiological importance of this difference can be only small, perhaps tending to a little more compactness of structure and precision of movement in the one form than in the other, the morphological significance is very great, for it is found that all the genera allied in other respects to the two neighbouring families, Cicindelide and Dyticidæ, belong to the first division, and all the highly specialised forms of pure Carabideous type belong to the second. The forms of the first division are therefore nearer the fundamental common type of the Adepaga than those of the second.

The first division is well represented in temperate latitudes. It comprehends all the true *Carabi* and the *Calosome*, large insects, remarkable for their generally brilliant metallic colours and elegant sculpture, the elytra being often scored with fine punctured lines, between raised interstices, which are consolidated in some species into a smaller number of rib-like elevations, and again in others are broken up into rows of tubercles. Of the genus *Carabus*, about 400 species are known. A good idea of their form may be gathered from our illustrations, in one of which are represented two individuals of *Carabus auratus*, a common French species, sometimes found on the south coast of England. One of the Beetles is engaged in disembowelling a Cockchafer, whilst one of the two larvæ is seizing an Ant. Our other illustration represents *Carabus adonis*, a large species of a rich violet colour, with golden borders to the wing-cases, which is found only on the classical Mount Olympus, in Thessaly.



CARABUS ADONIS.

The geographical distribution of the genus is remarkable. It is restricted, with the exception of one small group of species, to the north temperate zone, Southern Europe and Western Asia yielding the most species, and North America relatively the fewest. The



PROCERUS GIGAS.

single exception to this northern range is Chili, in the southern and coldest provinces of which, as far as the Strait of Magellan, a few species are found, of great splendour of colouring and elegance of form, constituting a sub-genus. The interval which separates this outlying antarctic colony from the northern main body has a width of seventy degrees of latitude, no species of *Carabus* having yet been met with in tropical America, nor, in the Eastern Hemisphere, in tropical Asia, South Africa, or Australia. The species are very numerous and varied in mountain ranges, the Caucasus, Pyrenees, Alps, and Altai being very abundantly stocked; a few remarkable species are also found in the Atlas range, and in the Himalayas and mountains of Southern and Western China. The genus is also remarkable for the extraordinary variability of its specific forms, the variations being often confined to definite localities, and tending to the formation of sub-species and representative species.

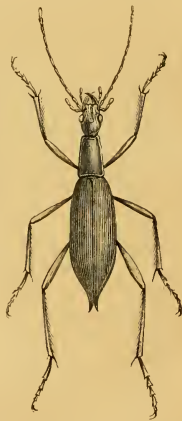
Carabus proper is the centre of a group of genera, some of which contain insects of very large size. Such is *Procerus* (of one species of which, *P. gigas*, we present a figure), containing a small number of bright blue and violet species,

restricted to South-eastern Europe and Asia Minor. Another is *Damaster* (see figure of *Damaster*

blaptoides), an eccentric form called the "fiddle-beetle" by the Japanese, to whose country the genus is confined. *Calosoma*, a genus almost as handsome as *Carabus*, is distributed over tropical and south temperate as well as northern regions, but does not reach very high latitudes or great alpine elevations. Some of the species have the remarkable habit of climbing trees in search of caterpillars, which constitute their prey.

Nebria is a numerous genus, of smaller size and slighter build, restricted to temperate and arctic latitudes, and *Elaphrus*, having a similar geographical distribution, is remarkable for its prominent eyes, like the Tiger-beetles, towards which family the genus is certainly an approximation; the species, of which four are found in Britain, are marsh insects, and are found running over damp earth in the sunny days of early spring.

Among the exotic forms of this section, the most extraordinary is *Amphizoa*, found in the valley of the Sacramento, in California. In the structure of its sternum and haunch-sockets, and in its naked antennæ, it resembles the true Dyticidae much more closely than any form of Carabidae, but its legs are formed for running, not swimming. Its place in a natural arrangement seems to be at the commencement, indifferently, of the two chief families of the tribe, indicating that it is a survival of some primitive form from which these families have branched by subsequent evolution. Another remarkable group are the *Ozenina*, medium-sized Carabidae, found in tropical and warm countries at the roots of plants or under the bark of trees. They have a small fold in the outer margin of the wing-covers, a feature which is observed elsewhere in no group but the very aberrant family *Paussidae*, described farther on. The numerous sub-family *Scaritidae*, or burrowing Carabidae, belong also to this first division, as do

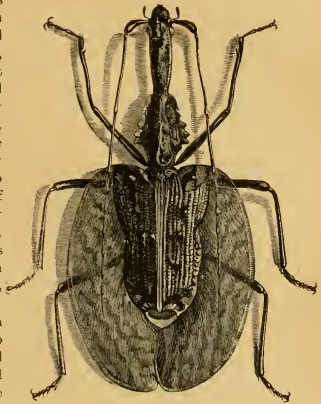


DAMASTER BLAPTOIDES.

also the allied group *Siagonina*, found chiefly in sandy districts round the Mediterranean. One significant character of the division is the disconnection which exists between the various sub-families

of which it is composed and the number of isolated forms it contains. One of these latter, the last we shall notice, is the *Mormolyce phyllodes*, which has no near allies (except two or three other species of the same genus) in the whole family, and looks like a monstrosity. It is found only in the Malayan Peninsula and the neighbouring large islands. It will be noticed, on examining our figure of this insect, that its anomalous form is chiefly due to the great expansion of the side borders of the wing-cases, and their prolongation in a curve beyond the ordinary termination of these members. Count Castelnau, who observed the habits of this extraordinary Beetle in its native forests, and who discovered two new species of the genus, says that it is found clinging to the under surface, close to the ground, of trunks of the largest trees, when these have been uprooted by storms, and that he never detected it under the bark, although its very flattened and expanded form seems to adapt it for such a habit. It probably preys on the larvæ and pupæ of insects infesting the boleti, with which damp bark is generally covered.

The second division of Carabide, or that in which the hindmost plates of the middle thorax do not reach the sockets of the haunches of the second pair of legs, is much more numerous in genera and species than the first division, but it is at the same time less diversified in its essential structural characters. It may be remarked also that its sub-families



MORMOLYCE PHYLLODES.



TEFFLUS MEGERLEI.

and genera are less strongly differentiated from each other, a phenomenon which can only be explained by assuming that there has been less extinction of intermediate forms, and that the type is posterior to the type of the first division in time and in grade of evolution. This assumption is confirmed by the study of other peculiarities in their organisation already noticed, namely, the notched anterior shanks and the fewer number of finely pubescent or sensitive basal joints of the antennæ, special features which do not re-appear in any other group of the Adephaga.

The male insects in this division are distinguished (as they are also in most genera of the preceding) by the feet of the anterior pair of legs being dilated, and the under surface of the expanded joints being furnished with a pad of short hairs or scales. The function of these dilated palms is to secure the hold on the female at the time of pairing, additional grasping or adhesive power being rendered necessary by the prevailing polished surface of the integument in this family of insects. They have been likened to hands, and Latreille, in drawing up his natural classification of the group, named the subordinate sections *Patellinani*, *Quadrinani*, *Simplificinani*, according to the shape and number of the "hands," and the clothing of the palms, some groups having one and others two pairs of dilated feet, and some having palms clothed with a smooth flat brush of hairs, whilst in others the hairs are replaced by ragged cartilaginous scales generally arranged in rows. These peculiarities form very constant characters, and are of great value in the classification of the family. It may be remarked that whenever the males have dilated feet in the first division (e.g., in the Tiger-beetles), the palms are clothed with a plane brush of hairs; the modification into scales appears first in the second division, and in the most specialised forms.

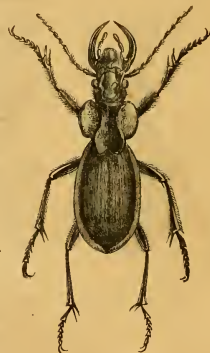
There are about 600 tolerably well-defined genera in this second division of Carabida, grouped under a proportionally large number of sub-families. Our space permits us only to allude to a few of the most remarkable forms of this immense assemblage. The starting point of the division is formed by the sub-family *Broschini*, a group resembling the *Scaritinae* of the first division in the thorax being separated from the elytra by a peduncle, formed by the exposed narrow mesothorax. The great majority of the species belong to the Southern Hemisphere, in New Zealand, Australia, and Chili. One (*Brosicus cephalotes*) is a well-known British Beetle, found under *débris* on sandy sea-shores. Another conspicuous sub-family is the *Panagæinae*, belonging to the "Patellimani," the first pair of feet in the males in the principal species having two or three joints dilated in the form of a platter. They prefer situations having a light sandy soil, and are distinguished by their minutely-sculptured roughened surface, and generally by the ornamental marking of their wing-cases, consisting of four bright red square spots, so arranged that the ground colour between them forms a black cross. *Panagæus crux-major* is a well-known British species. A gigantic black or metallic-coloured form of the *Panagæidae* is the genus *Tefflus*, found in numerous species in tropical Africa, in which region the red-spotted species also occur in great variety. Next to these come the *Licininae* and *Chlæniinae* sub-families. The *Chlæniinae* inhabit marshy places, and the margins of streams and pools. They are mostly of beautiful metallic colours, with elytra clothed with soft silky pile. Upwards of 400 species are known from nearly all parts of the world, tropical and temperate, and several are found in the British islands. The *Anchomeninae* and *Pterostichinae*, which next follow, contain the most abundant and widely-distributed Beetles of the whole family, and include the common Black-beetles of our pathways



HYPERION SCHROETERI.

(*Steropus malidus*, *Omasus vulgaris*), and the little oval bronzed Sun-beetles (*Amara*) seen so commonly running along pathways in spring. Australia is exceedingly rich in genera and species of *Pterostichinae*, and it is there that occurs the largest species of the sub-family, the *Hyperion schroeteri* of our illustration, two inches and a half long. In all the above the number of smooth, non-sensitive basal joints of the antennæ is three; in another series of sub-families there are only two; among these are the *Harpalinae*, and the *Anisodactylinae*, which have dilated patus to the four anterior feet of the males.

The last, or highest, sub-families of the division are those containing all the principal arboreal groups. But whether terrestrial or arboreal they may be recognised by the wing-cases being clipped short, or truncated, at their apices; hence the name of *Truncatipennæ* applied to the whole series. The genera are excessively numerous and varied, and the great majority are found only in richly wooded regions, chiefly in the tropical and sub-tropical zones of the earth. Most are of small or medium size, and of light graceful shape. The *Lebiinae*, which constitute one of the groups, and are tolerably well represented in Europe and in Great Britain, are extremely numerous in tropical America, where they live on low trees, and run with great ease and rapidity over the smooth broad leaves of *Heliconia* and other broad-leaved plants in moist situations. The *Callidinae*, larger and more linear in form, are another numerous group, but foreign to Europe; they are more exclusively arboreal than the *Lebiinae*, and one of their genera, the *Agræ*, are remarkable insects with narrow and elongated head, and thorax,



ANTHIA THORACICA

which live entirely on trees, and seek their prey at night, remaining during the day concealed in the folds of curled-up leaves. One large section of *Truncatipennæ*, however, are terrestrial insects, such as the Artillery-beetles (*Brachiniæ*), *Odacanthina*, and other sub-families, and another (*Coptoderinæ*, *Thyreopterina*) are bark-insects, *i.e.*, specially adapted for seeking their prey upon or underneath the bark of trees, where lignivorous and fungivorous insects of other tribes abound. The feet of these are not lobed, but their claws are in many genera finely toothed, a structure which enables them to maintain their foothold in running over the bark. Many run with great speed, and, owing to their flattened forms, slip with facility under slightly-loosened bark in pursuit of their prey. A large number of brilliantly-coloured and prettily-marked species, belonging to these sub-families, inhabit the forests of tropical countries.

Among the remaining families of *Truncatipennæ*, the most conspicuous insects for size, strength, and truculent aspect are the *Anthia*, which abound in open districts in most parts of Africa. They are essentially runners, their wings being rudimentary or absent, and they are reported to seek their prey with great activity among low bushes and herbage in sandy places. The truncature of the wing-covers is sometimes scarcely perceptible in this group. More than 100 species are known, grouped under eight genera. Our illustration represents a species common in South Africa, especially in Natal.

CHAPTER III.

CARNIVOROUS, ANOMALOUS, AND BURYING-BEETLES.

PENTAMERA (*continued*)—Family DYTICIDÆ, or Carnivorous Water-Beetles—Air-breathing Insects—Peculiar Mode of Respiration—Structure, Transformations, and Habits—Family GYRINIDÆ, or Whirligig Beetles—Curious Mode of Progression on the Surface of the Water explained—Family PAUSSIDÆ—Grotesque Forms—Kept as Involuntary Guests of Ants—Tribe PALPICORNIA—Family HYDROPHILIDÆ, Herbivorous Water-Beetles—Carnivorous Habits of the Larvæ—Families GERRYSIDÆ, PARNIDÆ, and HETEROCERIDÆ—Mode of Breathing by Air-bubbles carried beneath the Water by the *Parni*—Tribe BRACHELITRÆ: Family STAPHYLINIDÆ—Low Type of Structure—Families PSELAPHIDÆ and SCYDMENIDÆ—Blind Pselaphidæ, the Pets of Ants—Tribe NECROPHAGÆ or CLAVICORNIA—Heterogeneous Composition of the Tribe—Family SILPHIDÆ—Burying Beetles, and their Singular Habits—Families TRICHOPTERYGIDÆ, SCAPHIDIDÆ, PHALACRIDÆ, and NITIDULIDÆ—The Smallest Beetles known—Families TROGOSITIDÆ to HISTERIDÆ—End of the Necrophaga.

FAMILY DYTICIDÆ.

THE Dyticidæ are predaceous Beetles of the water, differing from *Carabidæ* chiefly in their legs, and the shape of their bodies being modified to suit their aquatic life. The oval, or boat-like, and compact general form and oar-shaped hind legs of the typical species are familiar to all young naturalists, as many species are amongst the most common living objects of our ponds and slow-flowing rivers. The principal other points in which they differ from *Carabidæ* are, (1) their smooth antennæ, destitute of minute sculpture and fine pubescence, which constitute the sensitive surface in those organs; (2) the greater development and more solid texture of their ligula, or tongue; and (3) the larger dimensions of the coxæ of their hind legs, which are in the typical genera soldered to the voluminous metasternum, or hind portion of the breast. With regard to these differences, it may be said that the smoothness of the antennæ is a necessary condition of their aquatic life, as a hairy surface under water would interfere with the free transmission of impressions through the organs, by the collection of air-bubbles on their surface. The great development of the hind coxæ, their consolidation with the metasternum, and the great volume of the latter, are in similar manner correlated to the increased work thrown on the hind legs, as oars, in propelling the insect through the denser element of water, stronger muscles, with firmer attachment surfaces, necessitating increased size and firmness of the segments of the body to which their legs are articulated.

Dyticidæ are most abundant in stagnant waters. When inactive, or hibernating, they conceal themselves in the thick tufts of aquatic herbage, or in the soft mud. They become active in the early spring, and may then be seen moving in the water by the propulsion of their strong hind legs, and coming at intervals to the surface to breathe. This function, indispensable to them as air-breathing animals, is performed by elevating the tips of their bodies on arriving at the surface, and taking in a supply of air for the stigmatic openings of their abdomen and thorax, under the tips of their wing-

covers; the anal segments of the body being depressed for the freer passage of the air. They are able to make good use of their wings, leaving the water and flying to distant ponds in fine summer evenings. For defensive purposes, they have the same faculty as the Carabidæ of emitting a fetid liquid, but where this has been observed it is not, as in Carabidæ, by the anus, but through the interval between the head and the thorax.

The larvæ, more voracious and fiercer in aspect than the adult insects, are hatched from the cylindrical eggs in early spring and in autumn. They are of similar general form to the larvæ of the Carabidæ, and differ from the perfect insects in their heads, as well as the other parts of their long bodies, being free and mobile. Their mouths are armed with long and sharp sickle-shaped mandibles, well adapted to seize their prey, which consists of the larvæ of other insects, even of their own species, fresh-water molluscs, and sometimes young fishes. They quit the water to undergo their transformations, excavating a chamber in the soil, in which they pass into the pupa stage, emerging in due time as adult beetles.

The family includes two distinct sub-types, which some recent authors are inclined to treat as separate families. In the one (*Halipline*), consisting of species of small, or minute size, some of the essential peculiarities of Dyticidæ are wanting, such as the natatory hind legs, which do not differ in form from those of many Carabidæ. The posterior haunches, in correlation, are also not enlarged in front, although differing from those of Carabidæ in other respects. A still more important differential character has been recently discovered by Dr. D. Sharp, namely, in the relations of the chief side-plate of the metasternum to the sockets of the haunches of the middle pair of legs. This piece



DYTICUS MARGINALIS.

(episternum) in the great majority of the true Dyticidæ is extended so as to form part of the orbit of the socket; but in Haliplinæ, as in all the Carabidæ, it is not. The Haliplinæ are, notwithstanding, essentially Water-beetles, and cannot be classed with the Carabidæ; they swim freely, though somewhat slowly and with an ambulatory motion through the water, and their hind legs, although not compressed and flattened into oar-like organs, are furnished with a fringe of long hairs, unlike anything presented by the Carabidæ, which assists them in their motion through the water.



HALIPLUS FULVUS.

LACCOPHILUS
VARIEGATUS.

The true Dyticidæ form three sub-families, the family type reaching its highest degree of development in the genus *Cybister*, in which the enormously expanded hind haunches are soldered to a metasternum of voluminous dimensions. They are found chiefly in tropical and sub-tropical countries. The genus *Dytiscus*, consisting of insects nearly as large as those of the genus just mentioned, inhabits chiefly temperate, and even high, northern latitudes. Six species are found in Britain, *Dytiscus marginalis* being one of the commonest pond insects, and the favourite tenant of many a juvenile aquarium. *Laccophilus*, a genus of smaller species, two of which are common in every English pond, have remarkably well-developed hind legs, and are excellent swimmers. The genus is widely distributed in all climates; the same is the case with *Hydroporus*, of which no fewer than fifty species have been found in Great Britain; but *Suphis*, and other allied genera, are confined to the tropics.

FAMILY GYRINIDÆ, AND THE ANOMALOUS FAMILY PAUSSIDÆ.

The *Gyrinidæ*, or "Whirligig Beetles," of the surface of our ponds and rivers, form the last family of Adephaga, and consist of a comparatively small number of genera and species, varying but little from a common type. They differ from the rest of the Adephaga in the absence, or where present, the slender, unjointed form of the external lobe of the maxilla, and in the possession of four eyes, the eye on each side being divided into two, one situated above for vision in the air, and the other below for espying what happens in the water. From the Dyticidæ, with which they agree in general form and habit, and in most parts of the structure of the mouth, they differ in their legs, the relative development of which is reversed, as it is here the anterior pair which are longest, whilst in Dyticidæ it is the hindmost. The two hinder pairs of legs are extremely short, broad, and compressed, modified, in fact, to suit their extraordinary mode of locomotion—a rapid skimming in curves or circles over the surface of the water. The rapid forward motion is produced by the quick fore-and-aft movement of these strong and well-knit members, and the curves by the long anterior legs, which, usually kept folded under the breast, are jerked out one at a time, so as to change the straight line of progression into a curve. When alarmed, they plunge into the depths of the liquid element, carrying with them a relatively large air-bubble to supply their needs until they return to the surface. The females lay their eggs on the leaves of aquatic plants, and the larvæ which emerge from them are remarkable for their general resemblance to small Centipedes, owing to the abdominal segments being furnished on each side with a slender conical process resembling legs, the terminal, or ninth segment, having four of these appendages, longer and more movable than the others. As these curious processes have been found—at least, the apical ones—to have a fine trachea, or air-tube, passing through them to their apex, they are supposed to serve as breathing organs.

HYDROPHORUS GRISEO-
STRIATUS.SUPHIS CIMI-
COIDES.

Gyrinidæ are generally distributed over the earth, but, as already observed, the type is but little varied. The common British species (*Gyrinus natator*) is a fair representative of the whole family, the most remarkable species of which are the *Porrorhynchus marginatus* of Java, with its long and triangular upper lip, giving a snout-like appearance to the front of the head, and the *Enhydus sulcatus* of Brazil, more than three-quarters of an inch in length. The *Gyrinus distinctus*

of our illustration is a continental European species, differing from our common *Gyrinus* by its more striated and less polished surface.

The family Paussidæ, which we have thought convenient to notice in this place, is one of those anomalous forms, numerous in the Coleoptera, whose position in any system is very uncertain. Some of their species are known to be tenants of the nests of Ants, and to be tended with care and jealousy by those insects; but nothing is known of the habits of the great majority, most of which are rare, and met with only in houses at night in tropical and warm countries, whither they are attracted by the lights burning in the rooms. If they are habitually guests of Ants, guarded and fed by them in the recesses of their nests, some of the anomalies in their structure might be accounted for, on the ground of the natural variations in the various parts of their structure not having been controlled by natural selection in the free struggle

for existence. Granted this, it would be easy to believe they are strongly-modified forms of Carabidæ, allied to the sub-family *Ozeninæ*, as Burmeister believed them to be.

The *Paussidæ* are oblong insects of small size, distinguished at first sight from ordinary Beetles by the extraordinary form of their antennæ. These organs run into all sorts of fantastic shapes in the different species; but inordinate width and bulk, and the tendency to a bulbous form in the terminal joint, are the most general characters. The number of tarsal joints is normally five; when there are only four, it is in consequence of the small basal joint becoming inconspicuous or wanting; in other respects the legs, as well as the form and proportions of head, thorax, and body, are not essentially different from the same parts in many Adephaga. A peculiarity of the elytra—the existence of a small fold and breach of continuity in the lateral margin, near the apex—is very significant from the point of view of a relationship to the *Carabidæ*, as this curious feature is known to exist nowhere else in the Coleoptera save in the group *Ozeninæ* belonging to that family. Their faculty of crepitation also speaks for the same relationship, for the *Ozeninæ*, as well as the Artillery-beetles, possess this rare property. Against all this, however, stands the widely-different position of the mouth, and the structure of its different parts. The mouth, instead of being at the anterior extremity of the head, as in the Adephaga, is on the under side; but passing by this, as probably caused by the bulky antennæ necessitating the strengthening of the forehead, it must be allowed that the totally different form and nature of the mentum, or chin, goes quite against any near relationship to any of the Adephaga; for the definite form and structure, and the size of this organ, are quite essential characters of the tribe. In the *Paussidæ* it never approaches the Adephagous form, but is a narrow transverse plate, often indistinct, and the lower lip, which in Adephaga is subordinate to the mentum, is here of greater relative development. The maxillæ, too, are destitute of articulated outer lobe; but these members are so eccentric in shape in the family that not much reliance can be placed on this point.

More than one hundred species of these grotesque Beetles are known, chiefly from the tropical regions of Asia and Africa; but one (*Paussus faviæ*) is found in South-western Europe. Some collectors in South Africa and in Australia have been able to secure a large number of some of the species by assiduous search in Ants' nests. With regard to their social relations to the Ants, less is known; but it appears that some kinds are really enforced guests of the Ants. Mr. Ayres, of Potchefstroom, declares this to be the case with regard to the *Pentaplatarthrus paussoides*. He found a large number of the insects by digging in the nests of an active species of *Formica* in the Transvaal, and observed the Ants dragging the Beetles into their galleries, further stating that they bring them out when the sun is shining, and pull them in again when clouds begin to appear. Other observers have noticed that the Paussi are not willingly guests of the Ants, but are forcibly seized and detained by them. A common Australian species is found under dried cow-dung; and Paussi are often found in South Africa under stones.

TRIBE PALPICORNIA.

The tribe Palpicornia have for their chief point of distinction among the Coleoptera the great length and slenderness of their palpi, which are longer and more conspicuous than the antennæ: these latter being short, of from six to nine joints only, the terminal ones thickened into a club. The maxillæ and their exterior lobes are unarmed. The typical genera of the tribe are aquatic, and have



ENHYDRUS
SULCATUS.

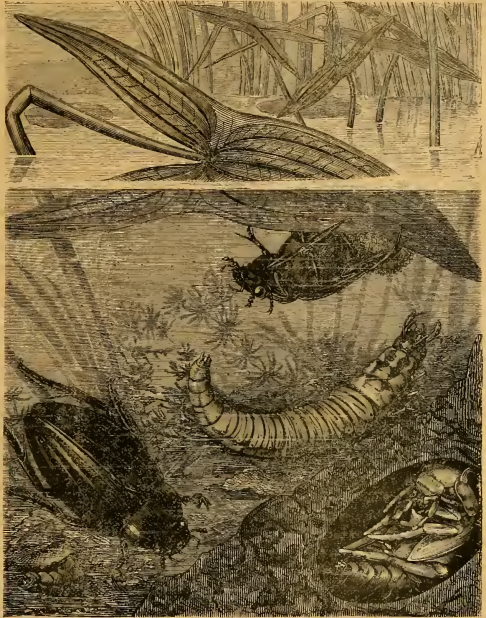


GYRINUS DIS-
TINCTUS.

hind legs adapted for swimming, like the Dyticidæ, from which the species are distinguished by their herbivorous habits, besides the fundamental differences in their antennæ and mouth organs.

The tribe consists of one family only (HYDROPHILIDÆ), containing five sub-families, of which four are water-insects, and the fifth, the Sphæridiinae, live on the dung of land animals. The aquatic series comprises the fine genus *HYDROPHILUS*, which vies with *Dyticus* in the size of its species. *Hydrophilus piceus* is a well-known inhabitant of our ponds, and one of the largest of the British Beetles. It is of more convex form than any species of *Dyticus*, and distinguished from them

also by its uniform deep black colour, and its less energetic motions in the water. Its mode of taking a supply of air is totally different from that of the Dyticidæ; for whilst the latter protrude the hind extremity of the body above the surface, the *Hydrophilus* elevates its head, and by a peculiar movement of the antennæ above the water, makes the air descend along the pubescent joints of the club, and thence to the fine hairs which clothe the flanks of the thorax, which pass it on to the stigmatic openings of the breathing tubes. There are some important differences, also, in the habits of the female insects with regard to the preservation of their offspring. The mother *Hydrophilus* weaves, by means of a tenacious fluid secreted by two spinnerets in the anus, a kind of cocoon, which she attaches to the under-surface of the leaf of some aquatic plant near the surface of the water, and which is provided with a tube



HYDROPHILUS PICEUS.

rising above the surface, destined to introduce a supply of air to the interior. In this cocoon she lays her eggs, to the number of about fifty, enveloped with a cottony substance. The larvæ emerge from the bottom of the cocoon at the end of six weeks, and swim forth in search of food; and it is remarkable that, instead of being vegetable feeders like their parents, they are carnivorous, and of extreme voracity. They are somewhat similar to the larvæ of *Dyticus*, but much thicker and more fleshy, covered with leathery, finely-shagreened skin, and the mandibles are toothed. Like the Dyticidæ, they crawl out of water to undergo their transformation into the pupa, and thence into the adult Beetle, burying themselves for the purpose in the damp ground.

The keel-shaped ridge running down the middle of the sternum of this insect, on the under side

of the body, and ending in a sharp point, is developed at the end, in some tropical African species, into a very long and sharp stileto, and serves, no doubt, as a defensive weapon. The allied genus (*Tropisternus*), of which there are many scores of smaller species in America, North and South, some of metallic colour and others striped with yellow, also possesses this armature. In *Hydrous caraboides*, a British species, next in size to *Hydrophilus piceus*, the keel is very short, not passing beyond the haunches of the hind legs. Besides these two large species, a considerable number of smaller Hydrophilidae are found in our ponds and streams, some, like the *Berosi* and the rare *Spercheus emarginatus*, wallowing in the soft mud at the bottom.

FAMILIES GEORYSSIDÆ, PARNIDÆ, AND HETEROCERIDÆ.

Some authors associate with the PALPICORNIA, or Philhydrida, the three families, GEORYSSIDÆ, PARNIDÆ, and HETEROCERIDÆ, induced to this course probably by considerations of convenience in reducing the number of detached families, rather than by any real similarity of organisation. The only constant points of agreement between these families and the Palpicornia are their aquatic mode of life and phytophagous habits. They vary much in the form of the antennæ, which are clavate only in some of the genera, and none of them have swimming feet; but in all the maxillæ and their lobes are, as in the Palpicornia, unarmed. As the only alternative is to treat them as so many separate tribes, we may introduce the little we have to say of them in this place.

The GEORYSSIDÆ are small insects of short, convex, and solid build, inhabiting damp places near water. Only seventeen species are known, chiefly from north temperate regions, but one or two have been of late years detected in Australia and Ceylon. Their antennæ have nine joints, the last three forming a club; the chin (mentum) is large and horny; the elytra are entire; the anterior haunches are cylindro-conic and exserted, and the posterior transversal; and the abdomen is composed of five segments only. The habits and early stages are unknown. One species (*Georyssus pygmaeus*) inhabits the British Islands.

The PARNIDÆ are little Beetles of oblong, sometimes nearly cylindrical, form, and of strictly aquatic habits. The principal species are clothed with a dense silky pile, which, on account of its hydrofugal properties, has the important functional effect of aiding in the respiration of the insects, by attaching to the body, at the moment of immersion, a globule of air sufficient for their needs during long periods of submergence in the water. Thus, with more facility than a diver in his diving-bell, the Parnus can move about the depths of the pool, carrying the needful supply with him in his wanderings. According to Erichson, the globule is surrounded by a thin film of oily or viscous matter, secreted by the hairs with which the body of the insect is clothed. The antennæ of the Parnidæ are variable in form in the different genera: in the sub-family Psepheninæ being saw-shaped; in the typical Parninæ clavate, sometimes lodged in repose for protection in a groove under the eyes, and bearing a branch-like process from their second joint; and finally, in the Elminæ filiform and simple. The mouth organs are feebly developed. The legs are slender, and the last joint of their feet is much elongated, with highly-developed claws. The latter peculiarity is of great importance in the economy of the species, most of which inhabit swiftly-running waters, and require grappling instruments, such as are afforded by these strong feet and long claws, to prevent their being swept from the roots and stems of aquatic plants, or from the mossy stones amid which they find their food. The longest feet and claws are seen in the sub-family Elminæ, these members reaching a truly remarkable degree of development in *Macronychus quadrituberculatus*, a rare and local British species, found in the river Trent.

The HETEROCERIDÆ, like the GEORYSSIDÆ, consist of one genus only. The family contains, however, upwards of seventy species, distributed over nearly the whole globe. They are not strictly aquatic, preferring damp, sandy, or marly soil, on the margins of pools and ditches. They differ from the Parnidæ farther in the larger development of the parts of the mouth, and in the feet, which are adapted for burrowing, being short and strong, with the shanks of the two anterior pair widened, and furnished on their outer edge with a row of spines. The insects, in fact, have the habit of burying themselves in the loose earth, in which labour their fossorial legs are aided by the robust head and the great mobility of the prothorax.

TRIBE BRACHELYTRA.—FAMILY STAPHYLINIDÆ.

This numerous tribe, of which the common British insect, the *Ocypus olens*, or Devil's Coach-horse, is a typical example, is distinguished by the much abbreviated elytra, these organs, in all but a few genera, being so reduced in length that they leave nearly the whole of the upper surface of the abdomen exposed. They are, however, always of oblong or square form, with straight hind margins, and meet in a straight suture. The membranous wings, of normal length, and adapted for active flight, are closely folded beneath. In correspondence with the abbreviation of the wing-covers, the upper sides of the abdominal segments are of horny texture, like the under; the segments, further, are all mobile, and the abdomen is thus capable of flexure in all directions. The habit of curving the tail upwards is very characteristic of these insects,

the tip of the body being used for pushing back the membranous wings, after flight, under the elytra; and in some small species it is carried habitually in a curled-up position, even in running. Many Brachelytra are of active predaceous habits, like Carabidæ; and in some of the genera, in which the elytra are much longer than in the majority, the resemblance to Carabidæ of the Truncatipennæ group is very great: but in these, as in the rest of the tribe, the totally different form of the chief parts of the mouth shows that we have to deal with a different type. The maxillæ differ from the same organs in the Adephaga in the outer lobe being never palpiform, though sometimes two-jointed, and the labium in being fully exerted beyond the upper edge of the mentum, the latter of which plays a subordinate part—the reverse, in fact, of what we see in the Adephagous tribe. This tendency towards a full development of the elements of the labium may be noted as an approximation to the mouth structure of the order Orthoptera, and as indicating a low position in the scale of specialisation of the Coleopterous tribes.

Many of the genera depart from the rule among the Pentamera section with regard to the number of tarsal joints. In some the four anterior feet have only four joints each; in many others four joints is the number to all the feet; and, again, some aberrant genera have only three joints. These exceptional cases, however, do not show any resemblance in the rest of their structure to the sections Tetramera and Trimera, to which they would be referred if the number of the tarsal joints were the sole character relied on. The antennæ are variable in form and in number of joints (nine to eleven); in extreme cases they are club-shaped. The sternal structure in the majority is remarkable for the atrophy or disappearance of the breastplates of the first segment, and partly of the second. In the insects thus



OCYPU'S OLENS (DEVIL'S COACH-HORSE) AND LARVA.

loosely knit the prothorax has extraordinary freedom of motion, to the extent of being capable of turning independently of the trunk; the sternum, however, presents more completeness and solidity in other of the sub-families, and in the Proteinæ resembles that of the family Nitidulidæ, in which the coxæ of the first and third hind pair of legs rest in transversal sockets.

The principal recent authors limit the tribe Brachelytra to the single family Staphylinidæ. The family is subdivided into eleven sub-families, and the number of known species at the present time does not fall far short of 5,000. They frequent the same haunts as the Carabidæ, and are distributed equally with them over all parts of the earth; they are, however, more varied in their habits. A large number of species are the guests of Ants, and are found only by assiduous search in the underground chambers of those insects. As many as 350 specimens, comprising seventeen species, chiefly of small Staphylinidæ, have been found by sifting the detritus of one nest of the Red Ant. Many of them are possibly only tolerated visitors of the Ants, resorting to the nests only in search of food. Multitudes of species live in the dung of animals, and in decaying animal and vegetable matter of all descriptions, some genera, of curious flattened form, being restricted to the confined spaces under slightly loosened bark of trees, and others to fungi and boleti. Their chief prey in these situations consists of other insects. They shun the daylight, and in the height of summer are scarcely ever seen abroad; but in early spring, and in warm evenings after sunset, they fly abroad in great numbers, seeking fresh hunting-grounds, and thus disseminating their species over wide areas. The larvæ resemble the perfect insects more than is the case in any other family of Coleoptera, affording another indication of the low rank of the Brachelytra in the order.

FAMILIES PSELAPHIDÆ AND SCYDMENIDÆ.

The PSELAPHIDÆ are a group of very small Beetles of anomalous structure, which bear a certain analogy to the Pausidæ, being, like them, of recondite habits, and—at least, in some well-established cases—the enforced guests of Ants. In both families the antennæ display great vagaries of form, and the parts of the mouth exhibit singular variations from the forms ruling in the allied groups. If, however, the hypothesis of anomalous modification be accepted, the Pselaphidæ must be admitted to be modifications of a different type from that which the Pausidæ were derived from; and just as the latter are possibly offshoots of the Carabidæ, the present family may be similarly related to the Staphylinidæ. Some authors, indeed, class them as a family of the Brachelytra. They have

similarly abbreviated wing-covers and horny dorsal segments of the abdomen, but here the similarity ceases; the mouth-parts differ in the soft membranous texture of the lower jaws and their external lobes; their abdomen (generally of five segments only) has little flexibility, and the tarsi consist only of three joints. The antennæ vary in the number of their joints from the normal number of eleven to six, two, and even a single joint, and are often thickened into a club of various forms. Sometimes they are short and rigid; at other times very long and bent into an angle, or肘ed.

The Pselaphidæ are distributed through all climates, being found in the tropics as well as in temperate and high northern latitudes. Many of the more extraordinary forms occur in Australia. We give a figure of one of the English species (*Pselaphus heisi*) which represents the ordinary shape of the family, and which, like most of the typical species, is found by searching at the roots of herbage on sandy banks, especially near water. The Ant-nest kinds are those which exhibit the strangest aberrations in the number and form of the antennal joints, such as the genus *Claviger*, in which these organs have only six joints, and all the parts of the mouth exhibit equally curious degradations of structure. These insects are totally blind, external eyes and optic nerves having alike disappeared, and they seem to be helplessly



PSELAPHUS HEISII.

dependent on the Ants for sustenance. A well-known British species (*Claviger testaceus*) is the guest of the Common Yellow Ant (*Formica flava*), passing its whole life in its nests, and being fed from the mouth of the Ants, and jealously guarded, with the object, as it has been stated, of securing a steady supply of a grateful liquid, secreted by the Clavigers from certain curious

pencils of hairs on the wing-covers, and from a cavity on the dorsal surface of the abdomen. According to a recent observation of Lespès, herds of these diminutive milch-cows, belonging to an allied species (*Claviger duvalii*) appear to be the hereditary property of certain families of Ants, who know their utility, other families of the same species, who have had no experience of such pets, refusing to tolerate them; he having found that Clavigers, when taken from one nest and put into another in a different locality, were immediately destroyed. The species of the allied genus *Articerus*, found in Australia, have been observed by Mr. Bostock, of Fremantle, to be also the jealously-guarded pets of Ants. One genus of Pselaphidæ is found in caverns in the South of Europe, some of its species being blind, and others furnished with excessively minute eyes.

The family SCYDMENIDÆ differ from the Pselaphidæ by their fully-developed elytra, which cover the abdomen to its apex. But they differ very essentially also in other respects, especially in their five-jointed tarsi and their abdomen of six segments. In general form and colour they closely resemble Pselaphidæ, and are met with in the same situations.

TRIBE NECROPHAGA, OR CLAVICORNIA.

Under the head of Necrophaga some modern entomologists include a large number of families which have scarcely any characters in common, except that of feeding on decaying animal or vegetable substances. As, however, they vary amongst each other in structure not much more than the Brachelytra—admitted to be a natural group—their association under one tribe is not without plausible grounds. The antennæ have a general tendency to assume a clavate form, that is, the terminal joints are more or less thickened, the three last sometimes forming a perfoliate club; but to this there are some exceptions, and in extreme cases the antennæ are long and simple. There are also, as in the Brachelytra, numerous exceptions to the rule of five-jointed tarsi and the loosely-knitted body. We observe, in fact, here, as in that tribe, all degrees of consolidation, commencing with species in which the abdominal segments—head, and thorax, and limbs—have all free movement, and ending with others in which the parts are more or less consolidated or locked together. We commence our review of the families with those which have the nearest relationship to the Brachelytra.

FAMILY SILPHIDÆ, OR CARRION-BEETLES.

The Silphidæ comprise, besides many genera of small and obscure insects, the conspicuous and gaily-coloured Necrophori, or Burying-beetles. In all, the abdomen has six free segments, and the antennæ are distinctly thickened or clavate at the tip. The insects which give their name to the family are further distinguished by their considerable, and sometimes large, size, their ovate or oblong, slightly-flattened form, and their rather long spiny legs. In the genus NECROPHORUS the elytra are shortened and truncated at the tip, leaving the end of the abdomen exposed. The family comprises also a group of Cave-beetles of strange form (Leptoderinæ), one genus of which (*Leptodirus*) has an excessively long and cylindrical prothorax, joined to a short, oviform hind body, destitute of membranous wings. The species are blind, and are found only in the most retired parts of caves in Carniola, hidden in fissures of stalagmites, or clinging to stalactites on the walls. They walk slowly, with body raised on their long legs, and when a sound is heard, suddenly lower themselves flat to the ground, with legs stretched out and antennæ elevated. Other genera, equally blind, and of the same pallid colour which distinguishes cave insects, present all gradations of form, between the eccentric Leptodiri and the ordinary-looking genus Catops, of which many species are quite commonly met with in England, in dried carcases or skins of animals in parks and similar situations.

Four or five species of Necrophori, or Burying-beetles, are not uncommon in England; one (*N. vespillo*), the handsomest, with its broad bands of bright orange and rows of yellow hairs, being frequently seen in streets and gardens in the fine days of spring, probably resting on its long journeys through the air in search of fresh booty. If we would see them in greater number, and at work, we have only to place upon light soil in a field, in some suitable situation known to be favourable to insects generally, a dead mouse, or similar small animal, and examine it a day or two afterwards. If the weather be fine, a number of Necrophori, sometimes of two or three distinct species, may then probably be caught in the act of burying the dead body. If we luckily time our visit at the commencement of the operation, we shall see them flying one by one from a distance, and settling near the edge of the carcase. They proceed by excavating the soil around and underneath until, in a few hours, by

the force of gravity, or by dint of various tugs by the Beetles themselves, the body is lowered, in some cases to the depth of a foot, and the loose soil closes over it. The mother Beetles then lay their eggs in the carcase, which are soon hatched, the larvæ being elongated fleshy grubs, widest in the middle, with three pairs of weak legs, and supplementary locomotive organs in the shape of a row of stiff spines on the dorsal surface of the body, proceeding from the hind edge of a horny plate, with which each segment is furnished. These spines, which are supposed to assist the larvæ in wriggling through the substances on which they feed, are more than an inch long when the insects are full grown. They then leave the carcase to undergo their transformations, burying themselves in the soil, and elaborating a kind of cell, with smooth inner walls, in which to change into the pupa stage. In about fifteen days they emerge as perfect insects, and fly abroad. The carcases buried by the Necrophori are usually devoured to the last morsel, the number of Beetles which apply themselves to this work being proportioned to the size of the dead body.



NECROPHILUS VESPILLO (THE BURYING-BEETLE).

Other genera of the family do not possess the burying instinct; the closely-allied *Necrodes littoralis*, which is also a common British insect, feeding and breeding in the interior of the carcases of large dead animals. Many of the true Silphæ, oval insects, with smaller heads, and wing-cases generally covering the end of the abdomen, prey on Snails, chiefly Helices, living as well as dead; and others on dead fish or reptiles, or the skins of dead animals; some live in trees, and feed on Caterpillars. The larvæ of

these have similar habits to the perfect insect, and, unlike their near relatives, the Necrophori, who are born in the midst of an ample supply of food, they search independently for their prey; their legs, therefore, are strong and well developed. The genera *Necrophorus* and *Silpha*, consisting of about one hundred and twenty species, are confined, with very few exceptions, to the north temperate zone. Their absence or extreme rarity in the tropics and warm temperate latitudes may partly be accounted for, perhaps, by their functions as scavengers being there performed by the ubiquitous Vultures.

FAMILIES TRICHOPTERYGIDÆ, SCAPHIDIIDÆ, PHALACRIDÆ, AND NITIDULIDÆ.

The TRICHOPTERYGIDÆ are a family of exceedingly minute species, many being less than one-fiftieth of an inch in length, the smallest of all known Beetles. They are found among decaying vegetable matter, the litter of old haystacks, under manure-heaps, and so forth. Their movements are lively, and those which possess wings fly well. The patience and industry of modern entomologists have been rewarded by the discovery of about one hundred and fifty species of these almost microscopic creatures, which have been subjected to careful examination, even in many cases to the dissection of the parts of their mouths, and they have been classified under ten well-characterised genera. The British

species and those of the Atlantic islands have been satisfactorily investigated by the Rev. A. Matthews ; but the group is by no means confined to temperate climates, several species having been found in India and Ceylon. In general form the Trichopterygide are oblong or oval, sometimes slightly flattened, sometimes convex ; generally finely pubescent, but often polished. Their antennæ are eleven-jointed, the three terminal joints forming a club, and their tarsi are three-jointed. The parts of the mouth present nothing remarkable, except the great development of the stem of the lower jaws, which is long and thick, and bears at its extremity the usual two lobes (or the blade and its outer lobe), both armed with fine teeth, the blade with one, the lobe with several. The wing-covers are sometimes much abbreviated, and sometimes entire, but the membranous wings beneath them are of extraordinary shape, and furnish the chief character as well as the name of the family. They resemble a miniature feather, having a slender horny stem supporting a lance-shaped membranous blade fringed with long hairs, which latter project when the wings are folded beneath the wing-cases. In some species the wings are rudimentary, and in others they disappear almost altogether. These latter are blind insects.

The SCAPHIDIIDÆ are Beetles of larger size, from one-tenth to a third of an inch in length, and recognisable by their short, thick, boat-shaped form, much narrowed both in front and behind, with glossy black or chestnut-coloured surface. Their antennæ and legs are rather long and slender, the former with their five terminal joints generally thickened. Their lower jaws are weak and membranous, their wing-covers clipped short behind, leaving the conical tip of the abdomen, of which the four apical segments are horny above, exposed. The tarsi are formed of five slender joints. These Beetles are very nimble on their legs, and fly well. They live and breed in fungi, and are sparingly distributed over the whole earth, under the Equator as well as beyond the Arctic Circle in Lapland. Some of the species are prettily spotted.

The PHALACRIDÆ are a group of small Beetles of short and convex form of body, having eleven-jointed antennæ, of which the three terminal joints are thickened into a very distinct club. The wing-cases are entire, covering the whole abdomen, and the abdomen is composed of five freely-articulated segments. The tarsi are five-jointed, the three first having fine brush-like palms, and the fourth being very short. Most of the few known species are found on flowers, and they fly well.

The NITIDULIDÆ are a very numerous family, distinguishable by the short, oblong, generally depressed form, with truncated wing-cases and antennæ terminated by a button-shaped club. The maxillæ, or lower jaws, are remarkable for the absence of the usual exterior lobe. The tarsi are five-jointed, with the fourth very small, and the abdomen consists of five free segments. The head is almost always retracted, and protected by the projecting lateral angles of the thorax. Eight hundred species are known, distributed over all climates, from the Equator to the Arctic Circle and the islands in the Antarctic Sea. In habits they offer great diversity ; for although the majority exhibit the necrophagous tendencies of the tribe, feeding and breeding in decaying vegetable and animal substances, such as fungi, rotten bark and wood, in the exudations of trees, and in the dried skins and carcasses of animals, a great number are found only on flowers. In tropical America certain species of one of the genera (*Carpophilus*) are seen in countless multitudes in the flowers of palm-trees ; and in Europe the little brassy Nitidulids of the genus *Meligethes*—true Flower-beetles—sometimes prove very destructive to cultivated plants, on account of their numbers. *Meligethes æneus* is one of the chief enemies of farmers in some parts of Germany for the injury it does to rape crops. These ubiquitous Beetles in many species are among the commonest insects of our fields in the summer, it being rare to find a wild flower untenanted by one or more individuals.

FAMILIES TROGOSITIDÆ, COLYDIIDÆ, RHYSODIDÆ, CUCUJIDÆ, CRYPTOPHAGIDÆ, LATHRIDIIDÆ, MYCETOPHAGIDÆ, THORICIDÆ, DERMESTIDÆ, BYRRHIDÆ, HISTERIDÆ.

We now come to a series of families, all that remain to be noticed of the tribe Necrophaga, which not only differ very materially in their characters from one another, but depart, each in its own way, from the chief features of the tribe.

The first (TROGOSITIDÆ) are closely allied to the Nitidulidæ in some parts of their structure, but they differ in important characters, the form of the lower jaws, and the tarsi, being peculiar, as in the Nitidulidæ, but in the reverse way : thus the lower jaws have only one lobe, but it is

the blade, and not the outer lobe, which is subject to disappear; and in the tarsi it is the first joint, and not the fourth, which is reduced in size. In their general form and habits also the two families are very different. The Trogositidæ are of much larger average size, longer and narrower in form (except in a few aberrant genera), and often of rich metallic colours. They are essentially wood-feeders, and are never found on flowers or in animal substances. Some few species, e.g., *Trogosita mauritanica*, have acquired a preference for wheaten flour and other kinds of cereal meal, and multiply at times in meal-bins, so as to prove a great pest to the miller and the baker. The family is generally distributed over the earth. About one hundred and fifty species have been described.

The COLYDIDÆ are a group of very small Beetles, living under bark or in rotten wood or fungi, of oblong and flattened or long and slender form, distinguished from the preceding family, *inter alia*, by their four-jointed tarsi. The abdomen, which in the preceding families of Necrophaga has all its segments free, here shows a more consolidated structure, only the last, or the last two segments being separately movable, a character which indicates a tendency towards a higher type than either of the two tribes Necrophaga and Brachelytra. The maxillæ have two lobes, and the antennæ are more or less clubbed at the extremity.

The RHYSODIDÆ are small wood-eating Beetles, of similar form to the more elongated genera of the preceding family. They are distinguished at first sight by the deep furrows which score the upper surface of their body in a longitudinal direction. Their antennæ are not clavate, but formed of rounded joints of nearly equal width, and eleven in number. About a dozen species only are known.

The CUCUJIDÆ are also wood-eaters, but more exclusively restricted to the bark of trees than the members of the preceding families. Their general form is oblong, and their colours pale or brown. Nearly all the numerous species are, in correspondence with this confined habitat, more or less flattened, some of them so much so that their bodies are scarcely thicker vertically than a sheet of ordinary writing-paper. The antennæ are long, often slender, eleven-jointed, with joints more or less rounded in form, the three last thickened into a club. The abdomen has six nearly equal segments, all free. The tarsi are normally five-jointed, but the hind pair in the males of many species have only four joints, and in many others the first or the fourth joint is much reduced in size. The mandibles are always well developed, and in some species are large and exerted. There are few exceptions in this family to the prevailing sub-cortical mode of life. One of these is furnished by the genus *Silevanus*, which infests sugar-casks and meal-bins. The species are sometimes found alive on the windows of our houses, or floating dead in our teacups. The flattened species are excessively numerous and varied in tropical America, living gregariously under the bark of recently-felled trees, so closely fitting that the blade of a penknife is with difficulty forced underneath.

The CRYPTOPHAGIDÆ differ in general appearance from Cucujidæ by their more oblong or elliptical form and pubescent surface. Nearly all are Beetles of very small size, inhabiting decayed wood, vegetable detritus, boleti, Ants' nests, and so forth. The antennæ are eleven-jointed, and have a distinct three-jointed club; the elytra are entire, covering the whole abdomen, which has five free joints; and the tarsi, with some exceptions in the males, are five-jointed. Most of the 300 species hitherto described are European, but many are found in Siberia and North America, and a few are known from warmer climates. The species of one genus (*Telmatophilus*) are found on aquatic plants; others of very diminutive size, belonging to the genus *Ephistemus*, attack mouldy paper, and are sometimes seen in old books in neglected libraries.

The LATHRIDIDÆ consist, like the preceding, of very small oblong or linear Beetles, of pale brownish colours, having antennæ of eleven joints, with a club formed sometimes only of one, at other times of two, and again of the ordinary number of three joints. The tarsi consist only of three simple joints. Their habits are very similar to those of the Cryptophagidæ. More than 350 species are known, of which a large number inhabit the British Islands.

The MYCETOPHAGIDÆ differ from the six preceding families in their oblong or oblong-ovate, convex form of body, fine pubescent clothing, and the ornamentation of their wing-covers with reddish belts or spots. Their antennæ are clubbed, and their abdomen consists of five movable, nearly equal segments. The tarsi have only four distinct joints, reduced to three in the anterior feet of the males. They live in boleti and fungi, or under the bark of dead trees.

The THORICIDÆ are a small group of minute, broad, and convex Beetles, remarkable for the great

relative size of the prothorax. Their antennæ are clubbed and eleven-jointed; their tarsi five-jointed. The first and last ventral segments of the abdomen are longer than the three intermediate ones. The species, only twenty in number, are peculiar to the countries bordering the Mediterranean.

The **DERMESTIDÆ** are a group of Beetles only too familiar to us by the destruction several of the species cause in our museums, or warehouses where animal substances are stored. They are oval or oblong insects, of small size, recognisable by their dense clothing of fine-laid hairs or scales, short clubbed antennæ, linear five-jointed tarsi, and the grey spots or belts with which their wing-cases are generally variegated. The larger species, belonging to the typical genus *Dermestes*, are the most voracious of all, living both in their larva and adult states in skins or bones of animals, furs, leather, salted meats, and so forth, and multiplying sometimes to a prodigious extent where these are long kept undisturbed. In consequence of these habits, and the frequency with which these objects are transported by ships in the way of commerce between one distant country or another, some of the species—as, for



DERMESTES LARDARIUS AND D. VULPINUS.

example, the *Dermestes lardarius* and *vulpinus* of our illustration—are very widely distributed. The pests of museums are of much smaller size, and belong to the genus *Anthrenus*, one of them, a notorious depredator, having the significant name of *Anthrenus museorum*. The larvæ of these insects are distinguished from those of all other Coleoptera by their clothing of long, erect hairs. Those of the above-named species of *Dermestes* are of more elongated form than the others, and taper towards the tail, which is armed above with two horny hooks; the long hairs are erect, except behind, where they are more rigid and directed backwards. The larvæ of the *Anthreni*, on the other hand, may be known by their more oval shape, the absence of hooks on the apical segment of the body, and the presence of numerous pencils of hairs on the sides of this and several preceding segments, which are susceptible of being raised at the will of the insect, and spread out in the form of a fan, which is at times set in active vibration. These larvæ feed on the dried fleshy parts of the substances they attack, concealing themselves from observation in the interior, where they pass through the pupa stage, and emerge by gnawing a hole when they attain their full growth as winged Beetles. It must be remarked, however, that the whole of the family do not partake of these exclusively necrophagous habits. Many resort to flowers in their adult stage, although bred in dried animal substances, and some are found in the larva state in rotten wood. The larvæ of *Anthreni* and *Attageni* have been found in winter in Swallows' nests, and those of another Dermestid (*Tiresias serra*) have been seen devouring the eggs of a Moth (*Liparis dispar*).

The **BYRRHIDÆ** comprise the curious olive-brown or greenish insects, of compact oval or round form, known familiarly as Pill-beetles. The head and legs in repose, or when the insect is alarmed, are retracted, the former within the prothorax, and the latter in depressions on the under surface of the body, the shanks being received within a groove of the thighs, and the feet within a similar groove of the shanks. The body is clothed with a very dense and short velvety pile, and some species are tinted with metallic colours between the velvety patches. They differ essentially from the Dermestidæ in the greater consolidation of the framework of the body; for whilst the latter have all the five segments of the abdomen freely articulated, the three basal segments in the Byrrhidae are soldered together. The more typical genera are peculiar to the northern temperate zone, the species being more numerous in Alpine situations, preferring light, sandy soils, where they appear to subsist on the roots of herbage

or on moss. In tropical America a genus named *Chelonarium* is found differing from the rest of the family by their filiform antennæ, concealed in repose in grooves along the breast. These are much less convex than the *Byrrhi*, and have a naked shining surface. They live on trees.

The last family of Necrophaga—the **HISTERIDÆ**—are recognisable at once from all their relatives by their general appearance, or facies, although this is subject to wide modifications. The majority are of compact oblong or nearly cubical shape, with solid glossy integuments of deep black or brassy colours, scored above with a few sharp striae, the head being retractile within the prothorax, and the gait much resembling that of a Tortoise. The general air of relationship is retained, although some of the genera are modified into oblong and flattened forms with exserted heads, and others are changed in an opposite direction into tiny cylinders—modifications corresponding with the changed mode of life of the species, the ordinary cubical Histeridæ living on dead animal and excrementitious substances, and in loose decaying vegetable matters. The oblong and flattened species are restricted to narrow crannies under bark, where they live in company with the equally flattened Cucujidæ, and the small cylindrical kinds bore into the trunks of trees. The last-named, belonging chiefly to the genus *Trypanus*, when seen at work at a dead tree, resemble little animated gnuets. They are furnished with sharp triangular heads, which are plunged into little holes in the wood, made by the jaws in places where the bark has been stripped off, and twirling their bodies the insects rapidly drill their way into the interior, a stream of fine sawdust meanwhile trickling from the holes. Some of the very large species with projecting mandibles feed on inspissated sap exuding from the crowns and stems of fallen palm-trees. As to the structural characters of the family, the chief distinctive features are the abbreviated and truncated wing-covers, and the short, retractile, elbowed and clubbed antennæ. Histeridæ are found in all climates, and are exceedingly numerous in generic and specific forms. About 1,200 species have been described.

CHAPTER IV.

THE LAMELLICORN AND SERRICORN BEETLES.

PENTAMERA (*continued*)—**TRIBE LAMELLICORNIA**—High Degree of Specialisation of the Tribe—Concentration of the Nervous System—Larvæ and Metamorphosis—Horned Species—**FAMILY LUCANIDÆ**, or **STAG BEETLES**—**FAMILY SCARABÆIDÆ**, or **TRUE LAMELLICORNIA**—Dung-feeding Scarabæidæ—The Sacred Beetle—Pill-rolling—A Parasitic Species—Burrows of Geotrupes—Leaf-eating Scarabæidæ—Cockchafers—Goldsmith Beetles—Rhinoceros and Elephant Beetles—Rosechafers—Goliath Beetles—**TRIBE SERRICORNIA**—Peculiar Structure of the Fore and Middle Sternum—**FAMILY BUPRESTIDÆ**—**FAMILY ELATERIDÆ**, or **CLICK BEETLES**—Fireflies—**TRIBE MALACODERMATA**—Glowworms—Object and Cause of their Light—**FAMILIES CLERTIDÆ**, **PTINIDÆ**, AND **BOSTRICHIDÆ**.

TRIBE LAMELLICORNIA.

THIS tribe comprehends all those conspicuous members of the Beetle order known by the names of Scarabæi, Cockchafers, May-bugs, Rosechafers, and so forth, which, by their large size, their great numbers, the singular habits and striking form of many of the species, and the great destruction many of them cause to trees and farm produce, have in all ages attracted popular attention. They are recognisable by the short antennæ being terminated by a lamellated club, formed by the three or more apical joints being elongated (on one side only), each into a little plate or "lamella," which are separately movable in the chief group, or Lamellicornia proper, and immovable in the Lucanidæ, or Stag-beetles. The parts of the mouth show a high degree of specialisation, in the great development of the solid horny mentum, or chin, and the subordination of the labial or lingual parts, which are more or less hidden within the mouth, behind the front edge of the chin. These characters, taken in conjunction with the consolidation of the abdominal segments, of which, in some genera, the connecting sutures of the ventral side are even obliterated, and a corresponding concentration of the nervous system, shown by the union—at least, in the highly-developed sub-families—of the ganglions of the hind body into a single large mass within the thorax, justify the views of those entomologists who have held that this tribe are the most highly organised of all Coleoptera. The legs in all the species are more or less long, and furnished with spines and transverse ridges, the shanks of the fore pair having one or more strong tooth-like projections on their outer edge, indicating fossorial or burrowing habits. The tarsi are always five-jointed.

There is more uniformity in the form of the larvæ and the nature of the metamorphosis in the Lamellicornis than in almost any other tribe of Coleoptera. A Lamellicorn larva may be known by its fleshy cylindrical form, curved inwardly towards the hind extremity. The curvature appears not to be under the will of the insect, except, perhaps, in its very earliest stage, and consequently the obese grub habitually rests on its side. Its skin is of fine, semi-transparent texture. Its head is rounded and horny, and furnished with strong mandibles, but destitute (with rare exceptions) of eyes. The thoracic segments bear three pairs of horny feet, and the ninth or terminal segment of the abdomen is greatly enlarged, and generally divided into two parts by a transverse furrow, simulating a division into two segments. The food of these larvæ varies according to the different sub-families, those belonging to the Coprophagous divisions living, like the adult insects, on the dung of animals, and the others generally on vegetable substances, living or decayed. The former pass through their various stages of growth rapidly, but the larvæ of the vegetable-feeding species are slow in reaching the pupa state. The slow-growing species, especially the Cockchafers, the life-history of many of which has been well investigated, take from two to three years. The mode of passing the pupa period of their lives is similar in all. The grub, namely, on completing its growth, forms in the soil an oval chamber, in which it undergoes the change. There are some exceptions to this rule, the most remarkable of which are certain cases in which species are parasitic on other members of the tribe.

The Lamellicornia include some of the largest and handsomest Beetles known; the sub-family Cetoniinæ, or Rosechafers, uniting elegance of form and beauty of colour in a remarkable degree. The horns, with which their head and thorax are often armed, and which imitate in shape in different species those of the Rhinoceros, the Goat, the Stag, the Reindeer, and other large animals, and their general herbivorous habits, have induced some authors to consider them as the analogues of the Pachyderm and Ruminant orders among the Mammals. Notwithstanding their bulk, they are, as a rule, strong flyers. The Cockchafers are well known for their capabilities in this respect; as is also the Geotrupes, "the shard-borne Beetle, with his drowsy hum" of Shakspeare. *Trichius fasciatus*, a handsome species, sometimes found abundantly in South Wales, flies about flowers with the activity of a Humble Bee, which it much resembles. Even the great Rhinoceros and Elephant-beetles of tropical America, weighted by their horny armature, fly long distances over rivers and lakes in sultry evenings. To sustain these efforts of prolonged flight, strong wing-muscles are necessary, and a well-developed respiratory apparatus; we find accordingly that the ordinary breathing tubes in these insects are not only greatly enlarged and ramified, but furnished throughout the body with supplementary air-vesicles, which act in the double capacity of lightening the specific gravity of the body and intensifying the aëration of the nutritive fluid, on which increased muscular volume and energy depend.

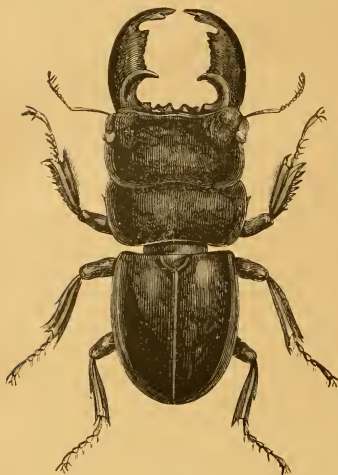
More than 7,000 species of this highly-endowed tribe have been already described, and numbers of new species are continually being discovered by travellers. They are divided into two families, very unequal in point of numbers, viz., the Lucanidæ, or Stag-beetles, and the true Lamellicornia, or Scarabæidæ.

FAMILY LUCANIDÆ.

This family is distinguished from the Scarabæidæ by the leaflets of the antennal club being fixed. This character is so constant that, added to the widely different general form of the insects, and the largely-developed projecting mandibles of the males of the majority of the species, it has induced many modern authors to consider the Lucanidæ as an independent group, totally distinct from the true Lamellicornis. If we look only at the extreme or more specialised forms of the two families, no other conclusion could well be arrived at; and it happens here, as in other large groups of Coleoptera, that the more specialised forms constitute the great majority of the genera and species of both families. On comparing, however, the less typical genera of the two, such as the *Æsalinæ* in the Lucanidæ, and some of the flat *Troginæ* in the Scarabæidæ, an approximation is observed between the two groups. If we trace the gradation of forms upward from this common point, we find, on the one hand, the Lucanidæ increasing in development of mandibles, with crown of head and thorax losing all traces of armature; while on the other hand, in the *Scarabæidæ*, the mandibles dwindle to useless, partly-membranous blades, and the horn-like processes on the head and thorax increase in size and variety of form.

About 550 species of Stag-beetles have been described. Being pre-eminently wood-feeders, and living in their larva stage in the interior of the trunks of large trees, they are found plentifully only in well-wooded countries; and in or near the tropics, where the forests are of varied kinds of trees, they present themselves in the greatest number and variety. We have in England only three species: *Lucanus cervus*, *Dorcus parallelipedus*, and *Sinodendron cylindricum*. The last-named

is found in all stages, sometimes in great plenty, in the interior of dead ash-trees. We figure a gigantic species of *Dorcus* found in Java. *Lamyprina*, a remarkable genus of metallic-coloured Stag-beetles, with straight mandibles, is peculiar to Australia; but the most eccentric form of the family occurs in Chili: this is the *Chiasognathus grantii*, which has excessively lengthened saw-like jaws, longer than the rest of the body.



DORCUS TITAN.

FAMILY SCARABEIDÆ, OR TRUE LAMELLICORNIA.

The host of species belonging to this second and greater division of the Lamellicorns are grouped under eleven natural sub-families, which themselves fall into two groups, according to the position of the spiracles, or breathing-holes in the sides of the abdomen. Seven sub-families, forming a legion called *Laparostictica*, have the abdominal spiracles all situated in the connecting membrane between the dorsal and ventral arcs of the abdominal rings. They are further distinguished by the ligula, or tongue, being distinct from the mentum. Four sub-families, forming the legion *Pleurostictica*, have the spiracles partly in the connecting membrane and partly pierced in the ventral arcs of the segments; in these the ligula is nearly always soldered to the inner side of the mentum.

To the first legion belong the numerous sub-family of *Coprina*, which include the greater part of

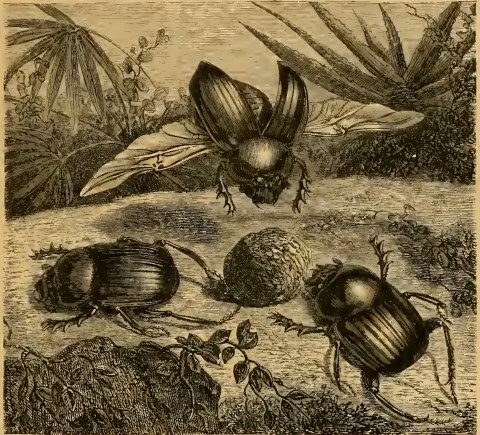
the dung-feeding Lamellicorns, and are distinguished by the front part of the head, or *clypeus*, being extended as a semicircular shield over the mouth, and the general absence of a scutellum. Many of them are fine insects, often of rich metallic colours, and remarkable for the horns and eccentric protuberances with which the head and thorax of the males are adorned. Such are the *Phanxi* of the warmer parts of America, and the *Onthophagi*, spread over all tropical and temperate countries; of the latter about 500 species are known, and the horns of the male insects are more varied in shape than in any other group. In one section of the sub-family the hind legs are elongated, and the tarsal joints short and of equal width; to this the sacred Scarabæi of the ancient Egyptians belong. These Beetles have the singular habit of forming pellets of dung, by rolling portions of this substance along the sandy soil by means of their long hind legs. It has long been taken for granted that the object for which these remarkable insects roll these dung-pills with such astonishing industry and pertinacity is to provide food in this form for their unborn progeny. The account generally given in books on natural history is to the effect that the pellets are rolled chiefly by the female insects, which deposit an egg in each, and trundle the precious burden, walking backwards, to a burrow previously excavated in a dry bank at some little distance. Often more than one individual is observed working at a pellet, especially when this falls into some hole, whence additional aid is necessary to extract it. Sometimes pellets have been seen stolen from the lawful owner by a brother Scarabæus, under pretence of giving help, and cases have been circumstantially related in which the males encourage and help their mates. The essential point in this curious



CERAMBYX HEROS, MALE (A); AND LUCANUS CERVUS (THE STAG-BEETLE), MALE (B) AND FEMALE (C).

history—the laying of an egg in the pellet—has, however, been called in question by a most accurate observer, M. Fabre, who declares, as the result of numerous and long-continued observations, that there are no eggs in the pellets. He has further shown that the dung is gathered and rolled and deposited in burrows solely in order to furnish a gluttonous feast to the Beetles themselves. The eggs, he believes, are deposited in a different way, in the midst of a supply of more succulent parts of the excrement. As to the stealing of pellets one from the other, M. Fabre confirms the statement, and gives a most amusing description of the different ways in which the robbery is effected.

In the typical genus *Scarabeus*, or *Atenuchus*, the semicircular clypeus is divided by sharp notches into a series of triangular teeth, and in repose the tooth-like projections of the anterior shanks flank the fore part of the body, owing to the fore legs being retracted. It is supposed to be either the resemblance to sun-rays thus produced, or the singular instincts of the insects, or both, that led to these Beetles being regarded as sacred by the Egyptians. The commonest species in Lower Egypt (*Scarabeus sacer*) is considered to be that most frequently represented on Egyptian monuments. This is a smooth black species; but a brilliant golden-green kind, named *S. egyptiorum*, found on the Upper Nile, the primitive home of the strange race who gradually spread over the lower valley, was believed by Latreille to have been the species originally worshipped.



SCARABÆUS SACER (SACRED BEETLE).

About seventy species of *Scarabeus* are known. They are confined to the Old World, having their metropolis in tropical Africa, where several species of great size and rich colours are met with. None are found in the north temperate zone. *S. sacer* occurs in all the littoral countries of the Mediterranean. In America the Scarabæi are represented by the genus *Canthon*, in Australia by *Cephalodesmus* and others, and in Madagascar by the brilliant *Epilissi*—all much smaller insects, but having similar habits.

The remaining Copridæ differ from the above by their much shorter hind legs, the tibiae of which are more or less dilated at the tip, and by the weak tapering tarsi. In this group, owing to the digging and burrowing habits of the species, some of which excavate galleries two or three feet deep in clayey earth, beneath the droppings of large herbivorous animals, the tarsi become of very subordinate importance, and in one South American genus (*Dendropæmon*) three of the joints disappear altogether. The females in this group deposit their eggs in unformed masses of pabulum, either drawn into the underground galleries excavated by them, or simply left on the surface.

The sub-family *Aphodiinae* have a projecting clypeus similar to that of the *Coprinae*, but they differ from the latter by their stronger and often armed lower jaws. They are also more elongated insects, with less voluminous sternum, and are nearly always provided with a scutellum. The genus *Aphodius* is copiously represented in temperate and high northern latitudes, and contains few tropical

species. All are strictly coprophagous insects, exhibiting no special instincts, but breeding in the substance which constitutes their food as adult insects. A remarkable exception to this uniform habit has, however, been discovered by Dr. Algernon Chapman, in the British species *Aphodius porcus*, which he found to be parasitic on *Geotrupes stercorarius*. He states that at about the time the parent *Geotrupes* closes the underground chamber in which she has laid one of her eggs with a store of food for the larva when hatched, the female *Aphodius* forces a way into it, eats the egg, which in volume is larger than herself, and having thus removed the prospective owner of the store of pabulum, lays her own eggs in little cavities which she forms in the pabulum itself, thus appropriating the supply of food for her own future offspring, and at the same time securing a snug asylum, free from the perils of the above-ground abodes of her sister *Aphodii*.

The genus *Geotrupes* forms the type of another sub-family of the section *Geotrupinae*, distinguished from the preceding by the small clypeus, which leaves the mandibles and other parts of the mouth exposed. In habits the species are similar to those members of the *Coprinae* sub-family which provide for their offspring by excavating tunnels or galleries under the droppings of large quadrupeds, and laying their eggs in these secure retreats by the side of a store of provender. But from the observations of Dr. Chapman we learn that the parent *Geotrupes* show much engineering skill in the formation of these underground nesting-places. In watching *Geotrupes stercorarius*, he observed that both male and female busied themselves in the work of carrying down pabulum into the burrows. These latter consist first of a vertical shaft underneath a cow-dropping, and then of a subsidiary gallery carried along the surface of the ground from this point to the edge of the dropping, where the removed earth is ejected. In the walls of these a number of small horizontal cavities are hollowed out at varying heights, each about an inch wide and four or five inches long, and in each a store of pabulum is placed and an egg deposited. The earth removed forms those little heaps of mould always seen by the side of droppings where *stercorarius* is at work. The rounded further ends of the cavities are firmly packed with concentric layers of dung, in the centre of which a kind of cell is made, the Beetles apparently working with their fore tibiae as trowels in making smooth the walls, and on the floor of this the egg is laid. The remaining part of the tunnel is packed with dung, layer by layer, before the work is completed.

Six species of *Geotrupes* are found in Britain, including the *G. typhaeus*, remarkable for the three horns projecting horizontally from the prothorax of the male. The genus is distributed over the whole north temperate zone, some of the species from South Europe and Japan being of bright coppery and golden colours. In Mexico and in Assam are found rare forms, having long vertical horns rising from the crown of the head. The allied genus *Bolbocerus*, of more spherical shape, and of pale reddish-brown colour, is most numerously represented in Australia, where the species exhibit great variety and eccentricity of form in the horns of the males: one species (*B. proboscideus*) having a long horizontal horn projecting from the head, slightly curving downwards, which simulates in miniature the trunk of an Elephant.

The sub-family *Troginae* resemble the *Geotrupinae* in the form of the head, but differ in the simple structure of the fore legs, which are not adapted for burrowing. The species live, in fact, on dried animal substances lying on the surface of the ground in sandy places, or on trees. Most of them are oblong or oval insects of moderate size, with rows of tubercles along the wing-cases, coloured like the sandy soil, and often coated with earthy material of the same colour. One group, however, which are found only on trees, and have the remarkable faculty of retracting their limbs, and closing themselves, like the Armadillo, into the form of little balls, are of polished metallic colours.

The sub-families of the *Pleurostictica* legion are the *MELOLONTINÆ*, or Cockchafers, the *RUTELINÆ*, or Goldsmith-beetles, the *DYNASTINÆ*, or Elephant- and Rhinoceros-beetles, and the *CETONINÆ*, or Rosechafers. All are vegetable feeders in both their larva and their adult stages—the great majority in their larva state feeding on roots of herbage, the remainder, including most of the *Dynastinae* and *Cetoniinae*, preferring decayed wood, some of the latter feeding on vegetable detritus in the nests of Ants. In their adult stages they offer more variety of habits. The *Melolonthinae* are chiefly leaf-eaters; many of the *Rutelinae* prefer fruit, although foliage and flowers are also resorted to; some of the *Dynastinae* feed on succulent plants and the exudations of large forest trees; whilst the *Cetoniinae* are pre-eminently Flower-beetles.

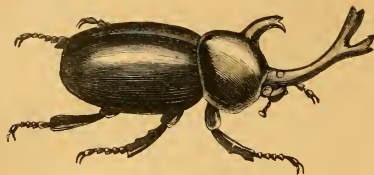
The MELOLONTINÆ are excessively numerous both in generic forms and in species, varying in size from a length of one-eighth of an inch to four inches. They are seldom of glossy metallic colours, the prevailing style of their livery being an integument of modest brown, coated with minute scales of white or grey, but sometimes of silvery or golden hue. Their organs of mastication are feebly developed, the mandibles being small, partly membranous, and not visible beyond the edge of the clypeus. The legs are long, with the hind tarsi formed of slender joints, and the claws, when both are present, as a rule divergent and toothed in the middle. Among the more remarkable subordinate groups of the sub-family we may mention first the *Hoplides*, small, compactly-built insects, with rich blue or silvery scale-clothing, distinguished by the more robust tarsi and the long unequal claws, very often reduced to a single claw curved like a grappling-hook. These are leaf and floral Beetles, of nimble flight, found in nearly all tropical and temperate regions, but nowhere in much abundance or variety except in South Africa, where some 300 species are met with, so varied in structure that no fewer than twenty-four genera have been found necessary for their classification. They are restricted to the southern extremity of the continent, comparatively few being found in the warmer district of Natal farther north, and, in short, they are the associates of the equally rich and peculiar flora of heaths and lilies of the Cape Colony. Another group, the *Sericides*, the most slenderly-formed of all the Melolonthinæ, of which we have two species in England, are copious! represented in Australia, where a numerous genus of gilded Chafers occurs, having a cleft clypeus, named *Diphucephala*. In America, North and South, the prevailing group are the *Macrodactylides*, elegantly-formed Beetles, with remarkably long and slender legs and feet, which are seen hovering in swarms over sweet-smelling flowers in open places on forest borders; a North American species feeds on the petals of roses. The typical group, *Melolonthides*, which includes the common Cockchafer and Midsummer-chaffer (*Rhizotrogus solstitialis*), is feebly represented in South America, Australia, and Africa south of the Sahara; but is rich in large and handsome species in the north temperate zone, in tropical Asia, and Madagascar. To this group belongs a series of species in which the leaflets of the antennæ are increased in number and developed to an enormous length, especially in the males. One of the best known is *Polyphylla fullo*, a common insect in France, twice the size of the Cockchafer, and prettily variegated with marble-like markings of a chalky-white colour. In some North American species the body is striped with white.

The Cockchafer (*Melolontha vulgaris*) seldom occurs in sufficient abundance in England to prove very destructive, either in its larva or perfect state. It is otherwise on the Continent, where, especially in France, it is developed in some years in countless myriads, the perfect insects stripping the trees of their entire foliage, and the larvæ destroying, by devouring the roots, not only the grass of pastures, but crops of all kinds of farm and garden produce, such as cereals, beetroot, strawberries, salads, and so forth. In a report on the ravages of the Cockchafer in 1865-6, presented to the Académie des Sciences in 1868, M. Reiset valued the damage done in the department of Seine-Inférieure in 1866 at more than one million sterling. The larva takes two years to complete its growth to the pupa stage, fourteen months of which are spent in active feeding, and ten months in dormant hibernation; the duration of the pupa state is eight months, and that of the adult Cockchafer three months and a half, three-fourths of which are passed underground, and one-fourth,



MELOLONTHA VULGARIS (COCKCHAFER).

or twenty days, only in the free, devouring leaves, pairing, and depositing its ova. Like nearly all its tribe, it is active only in the twilight hours of evening, concealing itself by day among foliage. In the years when it is abundant it devours the leaves of fruit-trees in gardens and orchards, as well as its favourite elms and oaks, poplars and birch being the last to be attacked.



XYLOTRUPES DICHOTOMA.

Notwithstanding the attention with which this destructive insect has been studied in France, no definite means have been discovered of checking its ravages. Farmers have been recommended, as one means of lessening their numbers, to plough and harrow their fields in early autumn, when the grubs are closer together and lie nearer the surface of the soil, and hand-picking has been suggested, as well as the encouragement of such useful insectivorous animals as the Mole and Shrew-mouse, and the various carnivorous Beetles, such as the Carabi.

In the United States of America an allied Beetle (*Lachnosterna quercina*), called the May-bug, is equally destructive to pasture land, and such is the completeness with which the larvæ do their work on the roots of grass, that turf may sometimes be peeled off in large sheets, like a carpet from a floor.

The *Rutelina*, or Goldsmith-beetles, differ from *Melolonthinae* in their much thicker tarsi, the joints of which are articulated closer together, and in their claws being unequal in size and not divergent. They are mostly Beetles of polished metallic integuments, and diurnal in their habits, the strength of the legs and the form of their bodies enabling them to cling firmly to the leaves of trees when not on the wing. One large section of the group may be known by the membranous border of their wing-cases. To these belongs the genus *Anomala*, of which about two hundred species are known from various parts of the world, one (*A. frischii*) being a well-known British Beetle. Some of the large tropical American *Rutelidae* are amongst the most brilliantly-coloured Beetles in existence: such are the species of the genus *Plusiotis*, whose burnished hides in some cases resemble silver or gold both in colour and texture. They are found on oaks in the mountains of Central America.

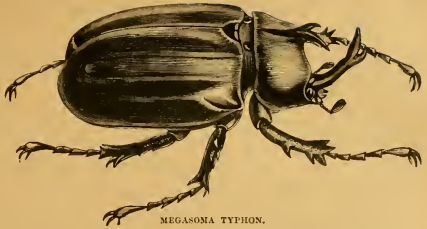
The *Dynastinae* are nearly all of sombre black or dark brown colours. The smaller species (*Cyclocephala*, *Ligyrus*, *Heteronychus*) show at most only the rudiments of the enormous horn-like processes with which the larger species are adorned. These weaker members of the group occur sometimes in tropical countries in countless swarms, especially in the sultry evenings which introduce the rainy seasons. At those times the town of Santarem, on the Amazon, is visited by such multitudes, attracted apparently by the lights of houses and shops, and flying with such speed, that the effect is like the pelting of a violent hailstorm. *Cyclocephala* frequent in large numbers the gigantic spathes of plants of the *Arum* family at the period of flowering, wallowing in the sticky pollen, and most likely serving in the cross-fertilisation of the plants as they pass from one to another. *Ligyrus bituberculatus* feeds on sugar-cane, and is known to be at times destructive to plantations in Demerara. *Xylotrupes gideon* and *Oryctes rhinoceros* attack the cocoa-nut palm in Malacca. Among the great horned species, which are equally abundant in the warmer countries of the New and Old Worlds, we give as illustrations *Xylotrupes dichotoma*, from China and Japan, *Megaceras chorineus*, from Cayenne and the Amazons, and *Megasoma typhon*, from Brazil. Others are known with much larger horns, such as *Dynastes hercules*, from Guiana and the West Indies, with its tapering thoracic horn projecting horizontally, and larger than all the rest



MEGACERAS CHORINEUS.

of the body, and the still more extraordinary *Golofa porteri* of New Granada, in which the horn rises vertically several inches high from the prothorax. The dark-bronzed *Chalcosoma atlas*, with long and sharp horns, three in number, rising from head and thorax, well known to collectors, is from the islands of the Malay Archipelago.

The *Cetoniinae*, or Rosechafers, are easily recognisable by their oblong, usually somewhat flattened form, the generally large triangular scutellum and the wing-covers not covering the apex of the abdomen. They are further distinguishable, on closer examination, by the upper lip being concealed under the front edge of the clypeus, and the mandibles reduced to thin membranous blades, with



MEGASOMA TYPHON.

a narrow outer margin alone horny. The typical or true *Cetoniinae* have a still more conspicuous distinguishing character, in the side piece of the mesosternum (or middle breast) being elevated, and introduced between the hind angles of the prothorax and the wing-cases. But this character fails in the group *Trichiides*, which forms the second division of the sub-family.

The *Cetoniinae* are the favourite group of Beetle collectors, a distinction they well merit for their unsurpassed beauty of form and colour, the facility of their preservation, and the great numbers and diversity of their species. To the classifier, however, they are less satisfactory, for all the structural characters on which he depends for the definite arranging into genera and higher groups prove here to be extremely unstable. At most, a few groups can be indicated by the agreement of their general figure, or "facies." About 1,200 species have been described. These are moderately numerous, and of little variety of form, in north temperate latitudes; in the corresponding zone of the south, as well as in oceanic islands generally (including New Zealand), they are entirely wanting. But each of the continents and large island groups within the tropical and warm temperate zones contains numerous peculiar genera, the richest being tropical Africa, Madagascar (which has a set of types distinct from those of Africa), tropical Asia, the Malay Archipelago, and Australia. America is relatively poor in *Cetoniinae*, but possesses its own very characteristic genera.



GOLIATHUS DEURYS. (Natural Size.)

At the head of the sub-family stand the Goliathides, or Goliath Beetles, distinguished by their large size, the horny processes with which the heads of the males are adorned, and the teeth bearing lower jaws, or maxillæ. Their head-quarters are tropical and Southern Africa, some few genera being peculiar to tropical Asia. Our figures represent



CERATORHINA POLYPHEMUS.

few genera being peculiar to tropical Asia. Our figures represent *Goliathus druryi*, from the Gold Coast, the largest of all the species, which is found by the negroes feeding at the sap of trees in the forest, and *Ceratorhina polyphemus*, an inhabitant of the wooded region extending from the Gold Coast to the Gaboon and Congo, and met with as far in the interior as the Muata Yanvo's domain in Central Africa. More than thirty species of *Ceratorhina* are known, one of the most beautiful of which (*C. petersiana*) has been taken at a village on the River Shiré, near Lake Nyassa, flying in great numbers about the flowers of a lofty tree, under which the native *palovers* are held. The ground-colour in these insects is a rich silky green, varied with stripes and spots of snow-white felted pile. The Madagascar series of forms consist chiefly of the *Schizorhina* group, destitute of horns, but having the front edge of the clypeus more or less notched. The same group constitutes the bulk of the Australian forms; but in the north, and in New Guinea, an allied group, called *Lomaptera*, of large size and great splendour of colour, is very numerous. The well-known European *Cetonia aurata*, common in the south of England, may be taken as a fair representative of the general form of the Cetoniinæ. In England it is found on various flowers, chiefly roses, hawkweeds, and other composite, in June and July, readily taking wing, and flying, like its congeners, with the wing-covers closed, instead of wide open like the majority of Coleoptera, a peculiarity due chiefly to the protrusion

of the side-pieces of the breast, already alluded to, in front of the shoulders of the elytra. The larva lives in decayed wood, and in the vegetable accumulations of Ants' nests, fabricating a sort of cocoon with agglutinated particles of the wood, in which to pass its transformations; and the duration of a generation, as in the Cockchafer, is three years. The second section of the sub-family, the *Trichiinæ*, are much less numerous than the Cetoniinæ, but some of their species are equally handsome. One of the largest (*Inca clathrata*) inhabits Brazil.

TRIBE SERRICORNIA.

The Serricornia form a numerous tribe of Beetles of elongate shape, furnished with antennæ short or of moderate length, most of the joints of which are more or less prolonged on the inner side, so as to give to the organ the appearance of a saw, or, when the prolongations are of greater length, of a comb. The tarsi, always five-jointed, are very often dilated, each joint (except the terminal one bearing the claws) being heart-shaped, or, as in many cases, furnished beneath with a membranous appendage. The head is almost always retracted up to the eyes within the prothorax, and this latter member is locked to the hind body by the projection of the prosternum being received into a cavity of the mesosternum. Thus, though often of great length and slenderness, the body in these insects is well knit, and adapted for movements of considerable vivacity and precision. The whole are vegetable feeders, but the larvæ and their habits offer much diversity, which will be further detailed under the head of the respective families.

FAMILY BUPRESTIDÆ.

This family is distinguished from the others of the same tribe by the fixity of the interlocking of the prosternum with the mesosternum, and by the solidity of their integuments and the short serrated antennæ. They are remarkable for the great beauty of their colours and markings, no other family containing so large a proportion of bright metallic-coloured species; and they are further remarkable for the uniformity of structure and general figure which characterises them as a group, notwithstanding the enormous number of their specific forms, of which nearly 3,000 have already been described. In

their habits also they offer little variety; the perfect insects, in the great majority of cases, frequent the trunks and large branches of felled trees in wooded regions. Here they may be seen sometimes in great numbers, nimbly walking over the bark or flying with great speed from tree to tree in the hot sunshine, and pairing, the females depositing their eggs in little cavities nibbled by them for the purpose. The larvæ of these typical species are elongated, somewhat flattened, pale, fleshy grubs, having the first of the thoracic segments abruptly widened, and only one pair of feet. On emerging from the eggs, the larvæ feed on the young wood between the bark and the solid trunk, undergoing in these places their transformations, or burrowing as they grow in size to the interior. Such are the habits of the majority of the family, including most of the larger and handsomer species of our museums. The smaller and broader species, forming the sub-family *Trachydinae*, differ much



CETONIA AURATA (ROSECHAFER).



CYRIA IMPERIALIS.

from the others, both in their larval form and their habits, the larva having six minute feet, and a horny plate on each of the abdominal segments above and beneath, the widest part of the thorax being at the middle segment instead of the first. In its habits it differs further in feeding on the parenchyma of leaves. Although the Buprestidæ are peculiarly forest insects, the northern species affecting the timber of coniferous trees, some have passed over to the cultivated trees of orchards. Thus, two species of *Chrysobothris*, *C. femorata* and *C. harrisi*, sometimes prove destructive to apple-trees in North America. As examples of this family, we figure *Cyria imperialis*, an Australian species, and *Chalcophora mariana*, a common insect in Central and Southern Europe. The species found in the British Islands are few in number and of small size.

FAMILIES THROSCIDÆ, EUCNEMIDÆ, AND ELATERIDÆ.

Two small families, THROSCIDÆ and EUCNEMIDÆ, hold an intermediate position between the great group BUPRESTIDÆ and the equally numerous ELATERIDÆ. The Throscidæ are small insects, resembling the Buprestidæ in the intimate union of the various parts of the body and the form of the interlocking apparatus of the fore and middle

sterna. Their antennæ are received in repose in narrow furrows existing for their protection in the sides of the prosternum, and their feet are contractile. About a hundred species are known, chiefly from South America. The EUCNEMIDÆ are distinguished by



CHALCOPHORA MARIANA.

their nearly cylindrical form, and the close approximation of the cavities in which the antennæ are inserted, which has the effect of greatly contracting the forehead. The antennæ are often beautifully branched. Nearly 500 species are known, chiefly from tropical countries. The ELATERIDÆ are more abundant in temperate latitudes than either of these two families, the species of Great Britain being familiarly known as "Click-beetles," from their singular habit of springing up in the air with a clicking noise when held in the hand on their backs, and thus, by reversing themselves, recovering the walking position. This action is produced by a vigorous tension of the muscles connecting the prothorax with the hind body, which raises the back above the surface on which the body lies, followed by a sudden relaxation, which brings it down again with force sufficient to make the insect bound into the air. The long, narrow, and flattish body, and the short and slender legs of these Beetles, render it otherwise very difficult, or even impossible, for them to turn over when by any accident they are cast on their backs. In accordance with this peculiar habit the sterna are not permanently interlocked, as in the Buprestidæ, but the long spine of the prosternum and the corresponding groove of the middle breast play a necessary part in the saltatory movement, in bringing the parts together after the strain and elongation of the thoracic muscles, the groove helping to guide the projecting point into the true axial position immediately the insect brings its prothorax down again and bounds upwards.



ELATER PREPARING TO SPRING.

The Elateridæ are well known also in their larva stage as the redoubtable Wireworms of our farmers and gardeners. These derive their name from their long, slender, cylindrical, somewhat rigid forms, so different from the club-shaped grubs of the Buprestidæ. They are generally wood-feeders, abounding often in rotten stumps; but many species are root-gnawers, and in this capacity attack all sorts of cultivated vegetable produce—the grass of lawns, cereals, and the plants of our gardens. Some of the species have been observed to live three years in the larva state, and to do in this time great damage to crops of corn.

JUMPING ORGAN
OF ELATER.

A remarkable faculty of one group of these insects is their luminosity: the Fire-fly of the West Indies and South America belonging to this family, and not to the true Glowworms. The light is emitted from two rounded spots on the prothorax, which are covered with a thinner and paler horny coating than the rest of the integument. Underneath each of these lamp-covers, within the thorax, is a vesicle of phosphorescent substance, which is luminous or not according to the will of the insect. The fire-flies belong to the genus *Pyrophorus*, and about ninety species are known from North and South America, differing in the degree of luminosity, some being destitute of lamps visible on the exterior. They are all night-flyers, and much less abundant than the true Glowworms of the same countries. The light is in some species emitted from the membranous parts at the articulation of the segments of the thorax, as well as from the rounded spots on the surface. Luminous Elateridæ, distinct as a genus from *Pyrophorus*, are found also in the New Hebrides Islands in the South Pacific. The larva of an Elater of the genus *Melanactes*, found in the United States, is also phosphorescent. We figure one of the *Pyrophori*, and also a North American species, *Alaus oculatus*, which has two eye-like spots on the prothorax, but is not luminous.

Allied to the Elateridæ are the two families CEBRIONIDÆ and RHIPICERIDÆ, the latter of which has in the males beautifully branched, sometimes fan-like or flabellated, antennæ. The middle sternum has no groove for the reception of a projection of the fore sternum. A few species only are known of either family, and none occur in the British Islands.

TRIBE MALACODERMATA.

Under this tribe are ranged a number of families which are distinguished for the softness or flexibility of their integuments and the absence of interlocking apparatus, and the consequent greater freedom of movement of the prothoracic division of the body. The antennæ are very variable in form, often thread-like and sometimes serrated, but rarely clavate; and the haunches of the anterior and middle pair of legs in all the typical species are salient and conical, in agreement with the general loosely-knit structure of the whole framework. The habits of the species are variable, and will be mentioned under each family and tribe. The larvæ differ greatly from those of the Buprestidæ and Elateridæ, in being of somewhat flattened form, and possessing firm or horny integuments; and in this stage carnivorous propensities seem to be generally characteristic of the tribe, although a large number in the adult stage are floral Beetles.

The two chief families of the tribe are the Dasyllidæ and the Malacodermidæ, or Malacodermata proper, the former consisting of species of oblong or PYROPHORUS NOCTILUCUS (WEST INDIAN FIRE-FLY), and the mentum, or chin, especially of horny texture; the latter of elongate, soft-bodied Beetles, with the mentum, or chin, often indistinct, blended with the membranous ligula,



ALAUUS OCULATUS.

or tongue, and the abdomen formed of six or seven free segments—characters which indicate a very low type in the Coleopterous series. Some of the insects belonging to this family are among the best-known of the whole order. Such are the Glowworms and the *Telephori*, or “soldiers and sailors,” so abundant in gardens in the early days of summer.

The first sub-family are the *Lycina*, Beetles of elongate flattened form, very generally widening behind, and of red or tawny yellow colours, banded with black. About 400 species are known, chiefly from the warmer regions of the earth, only three, belonging to the genus *Eros*, being found in the British Islands. The adult insects are met with chiefly on the leaves of trees, but *Eros minv-*

tus in England is taken in rotting branches of oak. The second sub-family are the Lampyrinæ, or Glowworms, distinguished from their allies by the prothorax forming a shield more or less

covering the head, and by their power of emitting light. This striking phenomenon, which has attracted popular attention in all countries where species of the family are found, is due, as in the Fire-flies, to phosphorescent particles concentrated in certain parts of the body. In the Fire-flies the sacs of luminous matter are contained in the prothorax; in the Lampyridæ they are localised in two or three of the abdominal segments. The two eminent anatomists, Köl liker and Macaire, are agreed that the granules which give forth the light are of albuminous nature; but Matteucci has assured himself by chemical analysis that they do not contain phosphorus. He says the luminous granules form part of a yellowish pulpy tissue lying underneath the transparent plates of the abdomen, which are visible in all Lampyridæ possessing the faculty, even in the dried specimens. This mass of tissue is permeated with nerves, and with ramifications of fine tracheæ, or tubes: the one supplying the air to feed the combustion which goes on when the light is shining, and the other the stimulus of the will of the insect. This description applies to the common European species (*Lampyris noctiluca*), abundant in many of the English southern counties. In this, as is well known, the female is wingless, resembling the larva state of the species, and gives forth a more brilliant light than the winged male. In very many exotic species both sexes are winged, some of the larger ones emitting a very conspicuous light, which, when many hundreds are seen at once—as often happens on dark sultry nights in the tropics—form a very beautiful sight, the phosphorescent lamps glittering in the bushes, or slowly moving and inter-crossing in the air, as the insects fly from tree to tree. Observers are agreed that these lamps serve as beacons to attract the sexes to one another; and the Rev. H. S. Gorham, who has studied a



LAMPYRIS SPLENDIDULA.

great diversity of species belonging to the family from all countries, made the curious observation that the different species vary greatly in the area of the luminous surface and in the size of the eyes, and that the eyes are developed in inverse proportion to the luminosity. He further remarks that wherever the light-emitting surface is confined to small spots only, and the eyes also are small, the antennæ present a high degree of development, being plumose, or branched like a feather, a structure which admits of a large extent of sensitive, probably

auditory, surface, a change of form the more significant, inasmuch as the Lampyridæ with large eyes, or with a high degree of luminosity, have simple and often short thread-like antennæ.

All known Lampyridæ are nocturnal in their habits, concealing themselves by day under dead leaves or about the roots of herbage. They are supposed to be vegetable feeders in their adult state; but the larvæ are carnivorous, feeding on land molluscs, in the interior of the shells of which the insects may often be found. The species we figure is the *Lampyris splendidula*, an inhabitant of Central and Southern Europe. Upwards of 500 species of this family are known, by far the greater number belonging to America, North and South.

The sub-family TELEPHORINÆ consists of species having a more elongated and narrower form than the preceding, with longer legs, and head not covered by the prothorax; one of the genera which connects the sub-family with the Glowworms is luminous. The family is abundantly represented in

temperate regions, twenty-five species of the genus *Telephorus* alone being found in Britain. The smaller species belonging to the genera *Malthinus* and *Malthodes*, often marked by pale spots at the tip of the wing-cases, are met with in abundance in hawthorn blossoms in spring. The next sub-family (DRILINÆ) contains a small number of species only, those whose habits are known, such as *Drilus flavesceus*, resembling the Glowworms in having wingless females, and feeding in the larva state on Snails. On chalk hills in the south of England it may be met with occasionally in the shells of the common *Helix nemoralis*. These insects differ in structure from the Lampyridæ, the head being free, and the antennæ inserted in front of the eyes. Following them are the numerous sub-family Melyridæ, of which there are in Britain six genera and seventeen species. They are floral Beetles, generally of metallic colours, and sometimes hairy. The species of *Malachius* are recognisable by their abbreviated wing-covers, spotted with red at the tip, and the curious small fleshy vesicles of red or orange colour which are protruded by the insects from the sides of the thorax and abdomen.

FAMILIES CLERIDÆ, PTINIDÆ, AND BOSTRICHIDÆ.

Associated with the Malacodermata by some authors are three families, which differ from the general character of the tribe in having integuments of normal horny consistence. The first are the CLERIDÆ, a numerous group, infinitely varied in colours and markings, and presenting many singular modifications of important organs, such as the antennæ. Amid all their varieties of form and structure, they may be distinguished from the Melyrinæ (their nearest allies), and from other groups of Malacodermata, by their tarsal joints being furnished beneath with flattened membranous appendages, and by the haunches of their hind legs articulating in transverse sockets. Nearly 800 species are known, from nearly all parts of the world; some, such as *Necrobis rufipes* and *ruficollis*—metallic-blue or green hairy insects, with red thorax or red legs, and clubbed antennæ—being among the most widely-distributed of all known insects, as they feed upon dried animal substances, bones, and the remains of food, and accompany civilised man in all his wanderings. Some of the larger species, belonging to the genus *Trichodes*, are of metallic colours, with wing-cases banded or spotted with bright red or orange. Many of these are common in Europe, and are well known for the destruction they cause in hives of the Hive Bee, as well as various kinds of social Wild Bee, their larvæ devouring the newly-hatched grubs of the Bees in their cells. Carnivorous propensities seem to be universal in this family, at least in the larva state; and even the gaily-coloured, innocent-looking adult Beetles, although frequenting flowers, are often noticed to seize and devour soft-bodied insects. A large proportion of the species, however, belonging to *Epiphleus* and allied genera, differing from the rest by their russet and inconspicuous colours and markings, are seen only on the trunks and branches of newly-felled trees, their larvæ living under the bark, and feeding on the larvæ of bark insects. Here the perfect Beetles may be found in tropical countries in the bright sunshine, running about with great agility, and vieing with the green and gold-spangled Buprestidæ in activity. Many others, such as the long, slender *Priocera*, which have serrated antennæ, are found slowly moving about the leaves and slender twigs of trees; and others (HYDROCERÆ, with short thread-like antennæ, clubbed at the tip, and many of the Enoptlinæ) infest the broad-leaved Heliconiæ and Marantaceous plants in American forests, running over the leaves, and preying on small Phytophaga. All the known larvæ resemble closely those of the Melyridæ, thus proving the close affinity of the two groups.

The PTINIDÆ are convex, oval, or rounded insects, with generally longish filiform antennæ. They breed in dead wood, and are often very destructive in their larva state, especially to furniture in houses and warehouses. The BOSTRICHIDÆ are of cylindrical form, with the three terminal joints of the antennæ forming a club, and are recognisable by the great convexity and roughened surface of the front part of the thorax, which hides the head when the insect is viewed from above. They are wood-eaters, and amongst the most efficient agents in the destruction of trees in the countries where they abound. One species (*Sinozyton sexdentatum*) is sometimes very destructive to the grape-vine in the south of France.

CHAPTER V.

SECTIONS HETEROMERA, TETRAMERA, AND TRIMERA.

SECTION HETEROMERA: Beetles with Five-jointed Tarsi to the Four Anterior, and Four-jointed to the Two Posterior Legs—Division of the Heteromera into Atrachelia and Trachelia.—Habits—Churchyard Beetles—Blister Beetles—Hypermetamorphosis—Singular Parasitic Habits and Mode of Development of *Sitaris*, *Melœ*, *Cantharis*, *Rhipiphorus*, *Hornia*, *Rhipidius*, and the *Stylopide*—SECTION TETRAMERA: Beetles with Four-jointed Tarsi—Family CURCULIONIDÆ, or Weevils—Family SCOLYTIDÆ, or Bark Beetles—Habits of some of the British Species—Families BRENTHIDÆ, ANTHRIDÆ, and BRUCHIDÆ (Seed-borers)—Tribe LONGICORNIA—Great Beauty and Variety of Form and Colours—Night flying and Day-flying Longicornia—Musk Beetles—Gigantic Species—Mimetic Resemblances and Protective Disguises—Branch-sawyers—Popular Errors on the Subject—Tribe PHYTOPHAGA, or Leaf-eaters—Strange Habits of some of their Larvæ—Tribe EROTYLIDÆ—SECTION TRIMERA: Beetles with Three-jointed Tarsi—Lady-birds.

SECTION HETEROMERA.

THE Heteromera, Beetles with five tarsal joints to the first and second pairs of legs, and four joints to the third pair, were divided by Westwood into two sub-sections, under the names of Atrachelia and Trachelia, the former including a host of forms of prevailing dull black colours (though some genera are metallic) and solid integuments, with the head sunk in the prothorax, the latter comprising all the remaining families, and distinguished by the exserted head, softer integuments, and more varied coloration.

THE ATRACHELIA form the single family TENEBRIONIDÆ of recent entomologists, one of the most numerous of the whole order, about 5,000 species having been described. Notwithstanding their number, and the great diversity in subordinate points of their structure, they have all a common air of parentage, which renders their recognition easy, and the general similarity is extended even to a peculiar and disagreeable odour which they emit. Nearly all are ground Beetles, inhabiting sandy districts about the roots of herbage or under vegetable detritus, feeding on these or on animal substances, and being nocturnal in their habits. A few live under the bark of trees and in boleti. The brighter metallic-coloured species live on trees, and are active by day. Some of the hard-bodied genera are known for their extreme tenacity of life, the most interesting example of which is that of a specimen of *Zopherus bremeri*, an insect about an inch in length, and of stony hardness of integument, which was exhibited alive by Mrs. Randolph Clay at a meeting of the Entomological Society of London, about a year after she had received it from Mexico. It was carried on her shoulder, secured by a gold chain round its waist, and had not tasted food since it had been in the possessor's hands. The family are remarkable for the mimetic resemblances which many of their species present: the form and garb of genera of other families, and particularly of the predaceous group Carabidæ, or of the lignivorous Longicornia, being most frequently assumed. The resemblance is so close in some cases that it is only by counting the joints of the hind tarsi that the true nature of the insect can be detected, without the dissection of the mouth. Preferring open, sandy districts, scantily or not at all wooded, the family is most numerous represented and most varied in comparatively desert regions, such as the borders of the African, Persian, and Central Asian deserts, the interior of North America, and the drier parts of Chili. Among the few species found in the British Islands, the most remarkable are *Blaps mortisaga*, or "Churchyard-beetle," *Helops pallidus* and *striatus*, and *Opatrum subulosum*, met with on sand-hills by the sea-shore.

THE TRACHELIA are less homogeneous than the Atrachelia, and have been divided consequently into numerous families. The first of these, the CISTELIDÆ, are slender arboreal insects, with pectinated tarsal claws. The NILIONIDÆ resemble certain convex Nitidulidæ, and are found in boleti in tropical America. The MELANDRYIDÆ and PYTHIDÆ are composed of a small number of species, inhabiting chiefly the north temperate zone of the New and Old World. Some of the latter, forming the genus *Salpingus*, have the head prolonged into a snout, and bear some resemblance to Weevils. The ANTHICIDÆ are minute, agile Beetles, bearing a wonderful likeness to Ants; many species are found in Great Britain, chiefly running over vegetable *débris* in sandy situations. Next to these comes a series of families allied to the Blister-beetle of commerce, some of the species of which are parasitic on other insects in their early stages, and exhibit the extraordinary phenomenon called *hypermetamorphosis*, that is, they undergo more than the normal number of changes in their growth from the newly-hatched grub to the pupa stage. This abnormal metamorphosis is connected with or necessitated by the peculiar conditions of their parasitic life, and presents features of great interest.

The first complete observations on the subject were made by M. Fabre, who studied the development of *Sitaris muralis* (family MELOIDÆ) with great perseverance and success. The Beetle is a well-known British as well as Continental insect, and was long suspected to be parasitic on the common Mason Bee, in the sense of living, in the larva state, on the food stored up in the cells of the Bee. M. Fabre discovered that it feeds on the eggs of the Bee as well as on the provision of honey stored up for the young, undergoing a singular change of form in the interval between the two operations, besides other metamorphoses, before assuming the ordinary pupa condition. The female

Sitaris, in the summer, lays her eggs in a mass glued together, at the entrance of the cylindrical gallery in a wall or bank within which the mother Bee constructs her cells. In the course of a month the young crawl forth in the form of little, elongated, six-footed larvæ, each foot terminated by a very sharp and movable claw, and the abdomen, near its tip, provided with two horny hooks. Contrary to all natural expectation, these larvæ, instead of searching for food straightway, remain for months fasting and motionless, until, in the early spring of the following year, the early Bees (always of the male sex) begin to emerge from the hole; then in an instant the sleepy larvæ start up, and fasten themselves with their strong grappling-hooks to their hairy bodies. From the male Bees they quickly pass, during union of the sexes, about a month later, to the females, and thus get conveyed to the newly-made cells, where, after the mother Bee has stored up a provision of



MELOË CICATRICOSUS.

SITARIS MURALIS.

liquid honey and laid an egg on the surface, the hungry larva slips off the Bee's body to the egg; in doing which it dexterously contrives to avoid being rolled off into the liquid, where it would infallibly perish. Alighting on the egg it quickly tears it, and commences to devour its contents. The repast lasts eight days, during which the little animal grows rapidly, and at the end, having completed its growth, and still mounted on the empty egg-shell as a raft, its skin splits down the back, and it enters its second stage. It is now a soft white grub, blind, and provided with only rudimentary feet. It has changed, in fact, from an active carnivorous insect into a blind and helpless honey-feeder, adapted to the condition in which it is placed, of having food in abundance without the need of searching for it. It tumbles off the egg-shell into the honey,

without risk now of being drowned, for all its breathing-holes are situated on the dorsal surface of the abdomen, and the ventral part alone is submerged. Thus it wallows until, having consumed all the honey, it undergoes another change, into what M. Fabre calls a "pseudo-chrysalide," a maggot of peculiar angular form, which remains motionless throughout the winter, and in spring changes its skin and appears as a larva again, completely resembling the form it had in the second stage. But it takes no nourishment, and in a short time changes into a pupa of the ordinary Coleopterous type, from which the winged adult *Sitaris* emerges at the end of a month. The whole series of wonderful changes occupies two years.

The other species of parasitic Meloide that have been observed have analogous, but in some points different, transformations and habits. Thus the species of Meloë, or Oil-beetle—of which one or two are common in spring on hedge-banks in many parts of England, and are recognisable by their short wing-cases, blue-black colour, voluminous abdomen, and greasy appearance—lay their eggs in holes in the ground previously excavated, and the larvæ, when hatched, attach themselves to Bees of various species. The only Bees on which they can profitably settle are such as make a provision of pollen-paste; and the active six-footed larva of the parasite, on completing its growth, changes into a fleshy cylindrical grub, with less aborted legs and stronger jaws than the corresponding stage of *Sitaris*. The parent Meloë lays an immense number of eggs, in little agglutinated masses and in many different holes, and the newly-hatched larvæ, climbing the stems of flowering plants, attach themselves with so little discrimination to any living hairy insect—Diptera or useless Hymenoptera—that large numbers perish by failing, through their faulty instinct, to be conveyed to cells where a store of pabulum is provided.

Certain genera of this family, more nearly allied to the Blister-beetle (*Cantharis vesicatoria*), and most probably some of the true *Cantharides* themselves, are parasitic on the eggs of Grasshoppers or Locusts, which it must be remembered are laid in masses enclosed in a cocoon-shaped envelope, aptly termed "egg-pod." The discovery of this singular variety of parasitism is due to Mr. C. V. Riley, who followed up the first indications he met with by a most complete series of observations on numerous species, both of Blister-beetles and Locusts, in the United States. The Beetles were, the *Epicauta cinerea*, *pennsylvanica*, *vittata*, and *marginata*, and the *Macrobasis unicolor*, Blister-beetles which, in their adult states, feed on the leaves of the potato. Their prey was the Rocky Mountain Locust (*Caloptenus spretus*) and other Grasshoppers of the same genus. He found that the parent Beetles lay their eggs, like the Meloë, in holes which they scratch in the ground, preferring the same warm sunny localities as the Locusts. The larvæ, in their first stage, somewhat resemble those of *Sitaris*, but are larger, more spiny, and have more powerful head and jaws and longer legs; strength and activity, in fact, are necessary to the creatures, who have to prowl about often for many days before finding the eggs which are to constitute their food. An egg-pod found, they precipitate themselves upon it with the utmost eagerness, fighting amongst themselves to the death for its exclusive possession, and gnawing their way through the shell to the contents. On becoming full-fed, about the eighth day, the active larva changes its skin, coming forth as a soft grub, with short legs. In this state it naturally lies in a curved position, but is active, and goes on feeding for about another week, when a second moult takes place, and it emerges as a more obese grub, with rudimentary legs, which is not materially modified a few days afterwards, when a third moult supervenes. In this last stage it grows apace, feeding continually on the rich juices of the Locust eggs, until at the end of another week it leaves its pabulum and burrows at some little distance in the clean soil, where it undergoes a transformation into the "pseudo-chrysalide" stage, in which the parts of the mouth become quite rudimentary, and no nourishment is taken. The insect generally hibernates in this stage, changing its skin in the spring, and coming forth again as an active larva, but only to burrow about in the ground, not to feed, and in the course of a few days changing into the true pupa, whence in a few days more the perfect Beetle emerges.

A further modification in the parasitism of this singular group is seen in *Rhipiphorus paradoxus*, a British species, whose life-history has been traced with great patience and acumen by Dr. Algernon Chapman. This insect feeds on the grub or larva of the Wasp. The mother *Rhipiphorus* lays her eggs in the cells of the Wasp, and the larva, on its emergence as a black active hexapod, similar to the first stage of Meloë larvæ, eats its way into the nearly full-grown grub of the Wasp, and feeds for some

time in the interior, without killing it, emerging after the grub has spun up for the pupa state. It then changes its skin, and comes forth in a shorter and thicker form, in which stage it attaches itself to the upper part of the body of its victim, and feeds by suction, soon afterwards undergoing a second change, and finally devouring the undeveloped Wasp entirely. When full-grown the *Rhipiphorus* larva closely resembles the grub of a Hymenopterous insect of the family of Fossorial Wasps.

In the *Hornia minutipennis*, another parasitic Meloïd, discovered by Mr. Riley infesting the cells of Mason Bees, the wing-covers in both sexes are reduced to minute scales on the sides of the middle segment of the thorax. This tendency to disappearance in the organs of flight is carried still further in *Rhipidius blattarum*, a minute European Beetle parasitic on the bodies of living Cockroaches, the female of which is apterous, and differs little in appearance from its larva, whilst the males have short divergent wing-covers and membranous wings. From this curious little Heteromeron, which feeds within the bodies of its victims, the transition is not unnatural to the family STYLOPIDÆ, a group of minute insects, which until recently were believed by all entomologists to constitute a distinct order of insects (STREPSIPTERA), differing from all others in the form of their wings, the parts of their mouth, and the relations between the segments of their thorax.

The Stylopidae are parasitic on living Bees and Wasps, the females being apterous and larviform, residing permanently in the bodies of the insects they infest, the males winged and active. The latter live but a few hours, and solely for the purpose of aiding in the propagation of the species, seeking the females, whose bodies are embedded, with the exception of a small upper portion, in those of Bees as they fly from flower to flower, and the orifice of whose reproductive organs lies in the exserted part near the head. The males take no nourishment during their short lives, and their mouth-organs are in a rudimentary condition, only the mandibles and one pair of palpi being recognisable. The head is extremely short and broad, the eyes prominent, the antennæ curiously forked, and the two anterior segments of the thorax relatively shorter and more closely connected together than in any other group of the Coleopterous order. But the most striking features are the greatly expanded membranous wings, coupled with the arrested development of the elytra, which do not serve as wing-covers, but are reduced to the form of slender appendages of thin texture, which in the dried specimens become twisted, and lose all similarity to the corresponding organs in all other Coleoptera. The tarsi are not heteromorous, but consist of two or four joints, and are destitute of claws. Such a combination of characters is not met with in any other group of insects, and lends justification to those entomologists who have treated the Stylopidae as a separate order. There is no part of their structure, however, which can be considered as quite incompatible with the Coleopterous type, except the extremely short prothorax, and the intimate connection of this segment with the middle thorax.



STYLOPS SPENCEI.

The early stages and mode of development of the Stylopidae are not essentially different from those of the Meloïdæ and Cantharidinae, already described. But the females are viviparous, the eggs hatching within their bodies, and the young crawl forth from an orifice situated in the part of the body of the parent which projects from the abdomen of the Bee. One female gives birth to many thousands of these tiny larvæ, which are moderately active hexapods, and resemble the first stage of the larvæ of *Sitaris*. They crawl forth and attach themselves to the hairs of other Bees, and are by them carried to their cells, where they penetrate the bodies of the Bee-grubs and feed on their substance, undergoing changes not very dissimilar to those of the Meloïdæ, the larvæ in their second stage being footless and blind; they continue to live in the interior of the Bee without destroying its life, or hindering it in its growth from the larva state to the chrysalis and adult Bee, only in their later stages protruding the anterior part of their bodies between the abdominal segments of the Bee. The female *Stylops* stops in its development at this stage; the male emerges from its pupa skin in the winged form we have already described.

Such in brief *résumé* is the life-history of these extraordinary little insects. According to an exhaustive monograph published by Sir Sidney Saunders in 1872, the diversity both of structure and habits among the species composing the group is much greater than was until quite recently supposed. One of them, which inhabits Ceylon, is parasitic on the workers of an Ant, and many species prey

upon Wasps, both of the social and the solitary genera ; but the most aberrant of all the Stylopidae is a kind which has been found in the abdomen of an insect of the order Homoptera, from Borneo. Eight species are found in England.

SECTION TETRAMERA.

We now arrive at the third great section of the order Coleoptera, distinguished from all others by the atrophy of the fourth tarsal joint in all the feet, by which these members have only four freely-articulating joints. The atrophied joint is in most cases extremely minute, and concealed in the deep notch of the third joint, which latter is in the vast majority of the species bi-lobed, and clothed beneath with a brush of minute hairs. The section is nearly equal to the Pentamera in the number of its described species, and forms more than a third of the total contents of the order. All the species are vegetable feeders.

FAMILY CURCULIONIDÆ.

The CURCULIONIDÆ, or Weevils, are recognisable by the head being prolonged into a rostrum, or "snout," which bears at its extremity the organs of the mouth. With the exception of the upper lip, all the buccal organs are complete, and exhibit a high degree of development or specialisation, the ligula, or tongue, being in a portion of the family concealed by the mentum. The antennæ are nearly always terminated by a club, and in the most numerous subdivisions are geniculate, or elbowed, the first joint or scape being proportionally very long, and the remainder, or flagellum, being set on at an angle to it: the joints between the scape and the club, which are often gradually thickened, are called together the "funiculum." The abdomen is composed of five, rarely of six segments, and the pronotum, or dorsal plate of the prothorax, is blended with the side pieces of the pectoral segment.

Weevils are among the commonest of all Beetles in temperate as well as tropical countries. About 12,000 species have been described, but it has been computed by a learned student of the family that not fewer than 30,000 exist in nature. They attack, principally in their larva stage, every part of vegetable tissues, and all forms of plant life, from cryptogams and the tenderest shrubs to the largest forest-tree: buds, leaves, flowers, fruits, seeds, nuts, stem, bark, wood, pith, and roots are all equally their prey, the species very generally confining themselves to their own special variety of food, and many restricting themselves to one kind of plant, a habit which partly accounts for their vast numbers ; for owing to this and their varied tastes, a score or more of distinct species are accommodated by a single species of tree, and are adapted in structure and habits to the limited conditions prescribed by such a mode of life. The adult Beetles are not in themselves, as a rule, injurious, but the larvæ, in very many cases, are very destructive, not only to forests and orchards, but to seeds and cereals stored in warehouses. They are footless, cylindrical grubs, somewhat narrowed and curved behind, and of rather firm integuments, and are distinguishable from the similar grubs of Lamellicorns, besides the absence of feet, by their atrophied antennæ. Some few species, leaf-miners, have straight bodies, and the larvæ of the Calandra group, so destructive to grain and to sugar and palm-tree plantations in the tropics, differ in being flexuous instead of simply curved towards the tail. Most of them pass their transformations within the vegetable substance which serves as their pabulum, constructing a sort of cocoon ; but some crawl forth and bury themselves in the soil before changing to the pupa state.

The classification of the vast multitude of forms constituting this important family has been found a most difficult problem, and within the past twenty years it has been remodelled from its foundations several times by entomologists who have made the subject their study. Previous to that time, the obvious division into Weevils with straight antennæ (Orthocera) and Weevils with geniculated antennæ (Gonatocera) was the prevailing system, the second or larger division being again subdivided, according to the length of the rostrum. This classification was overthrown by the celebrated systematist, Lacordaire, on the ground of its violating the really natural affinities of the forms, and he divided the whole family into "legions," according to modifications in the structure of the minute parts of the mouth. Still more recently, Dr. Leconte, of Philadelphia, in a learned monograph on the Curculionidæ of the United States, proposed an entirely different system, grouping the family primarily according to sexual differences in the abdomen, and the presence or absence of a lateral fold on the inner surface of the wing-cases. Under these chief

divisions are comprised a large number of sub-families, into which our space does not admit of our entering, and we must confine ourselves to a brief mention of some of the most interesting species.

One of the most important of the sub-families, in its relations to man, are the Calandrinae, or Weevils proper, which include the *Calandra granaria*, a small species, well known throughout Europe for the devastation it causes in granaries, the females, in the usual manner of Curculionidæ,



RHYNCHOPHORUS PALMARUM.

laying their minute eggs in little holes previously nibbled by them in grains of corn; the grub, which soon hatches, rapidly devours the contents, without affecting the whole appearance of the grain, and undergoing its transformation inside, emerges as a winged Beetle in forty or fifty days after the laying of the egg. Many generations succeed each other during the warmer months of the year, and the Beetle thus multiplies indefinitely. An allied species (*Calandra oryza*), causes similar injury to stores of rice and maize in India and other tropical regions. These are the *minims* of the sub-family; others belonging to the genera *Rhynchophorus* and *Macrochirus* reach a

great size, and are among the largest Beetles known. These are not granivorous, but live in the stems of succulent plants and trees, especially palms and bananas, several kinds being very destructive also to the sugar-cane. The fat grubs of a species of *Rhynchophorus*, found in sugar-plantations



RHYNCHITES BACCHUS.

in Guiana, contain in their entrails lumps of sweet wax, secreted from their saccharine pabulum, and are boiled and eaten by the natives. We figure a species of this genus, with its obese larva *in situ*. The species of the brilliant metallic-coloured genus *Rhynchites*, belonging to the old section *Orthocera*, attack various fruits. Many species are common in Europe, and seventeen are inhabitants of the British Islands. The females lay their eggs in the newly-formed fruit of apples, pears, plums, &c., piercing first holes for the purpose, and afterwards notching the peduncle of the fruit, so that it soon dies and falls. *Rhynchites bacchus*, a species of a rich golden-purple hue, and a quarter of an inch in length, sometimes proves very destructive to the pear crop in France. *Apoderus coryli* attacks nuts, and is common on hazel-trees in woods in England. The allied

genus *Apion*, small blue-black Weevils, with pear-shaped bodies, prey upon the seeds of leguminous shrubs, especially vetches, and are of great number and variety. The species belonging to the genus *Larinus* affect plants of the *Compositæ* order, the larvæ feeding on the flowers, forming little cocoons by gluing together fibrils and fragments of the inflorescence. A large number of Curculionidæ pass their early stages in the pith of stems of trees and plants. One small group (*Orchestes*), remarkable for their thickened hind legs and faculty of leaping, are leaf-miners in their larva state; as many as ten or twelve of the larvæ of *Orchestes pratensis* have been seen in discoloured patches on the leaves of *Centaurea scabiosa*.

FAMILY SCOLYTIDÆ.

The Scolytidæ are pre-eminently wood-borers, consisting of small cylindrical or oblong-oval Beetles, well fitted for their functions by their short, strong-toothed mandibles, flattened and dentate anterior legs, and the grater-like surface of their prothorax. Many of their species attract attention by the curious verniform, branched, and radiating galleries which they sculpture in the inner bark and adjoining hard wood of trees in our parks and avenues. They are effectively distinguished from the Curculionidæ by their linear naked tarsi, and very short and broad muzzle. The result of their labours is to destroy the bark, whereby the trees themselves are rendered easy prey to internal wood-borers. The destruction caused by the numerous species in the royal or national forests of France and Germany has led to their habits being closely studied on the Continent by many eminent observers, and recorded in voluminous treatises.

In Great Britain much curious and original information regarding native species has been furnished by Dr. Algernon Chapman. A peculiar feature in their habits is the co-operation which has been observed between the sexes—the adult insects—in the work of wood-burrowing; and another is the performance of the functions of pairing and ovipositing, like the transformations—at least, in some of the species—within the burrows. This latter, however, is not continued, as may well be imagined, from generation to generation, such breeding in-and-in being abhorrent to nature, judging from the various ways in which it is guarded against throughout both the animal and vegetable creations; crifices of exit from the galleries, therefore, always exist, by which the winged adults are free to go forth and pair with members of other colonies. The trees preferred by the Scolytidæ are elms, ash, oak, poplar, and various coniferæ and fruit-trees; and when they have secured undisturbed occupation, they have been known in a short time seriously to thin whole forests. The greater number of the species affect the inner bark, or cambium layer, of the trees, the work commencing by the parent insect burrowing a gallery, along the sides of which she lays her eggs, the larvæ on being hatched forming their burrows at right angles to that of the parent, the burrows diverging as the grub increases in size, so that in time they assume that fan-like appearance which is so commonly seen. *Hylesinus rugini*, the common burrower of the ash-tree in England, is stated by Dr. Chapman to prefer recently-fallen timber to the living tree; and in the first attack the female commences the burrow, the male not beginning until she has quite buried herself within. In the course of a few days, however, both



APODERUS CORYLI.

are busily at work, extending the gallery in both directions close to the hard wood, and scooping a surface-groove upon it. In the course of time, and after the deposition of eggs, from fifteen to one hundred in each burrow, the original female, and often the male, dies, their dead bodies remaining in the galleries for years afterwards; but the perfect insects of the new generation, which emerge from the pupæ at the ends of the larval burrows in the autumn of the year in which they were first hatched, gnaw a channel of exit, in the following spring, to the surface of the tree, and fly away. *H. crenatus*, a larger species, affecting also the ash, prefers living trees, and takes two years to complete its transformations. Another species, *Cryphalus binodulus*, attacks the aspen, utterly destroying the tree, beginning with the branches and working downwards; and *Scolytus destructor*, also common in England, the elm, destroying not only the inner bark, but burrowing half an inch deep into the solid wood. The numerous species of the genus *Platypus*, and its allies, differ in habits in some particulars from the rest of the family; at least, the English species, *P. cylindrus*, is found to burrow in the solid wood of oaks and beeches.

The other families of the Rhynchophora are the BRENTIDÆ, ANTHREBIDÆ, and BRUCHIDÆ.

The first-mentioned are very elongate, narrow Beetles, with rostrum long and filiform in the females, and shorter and broader in the males, the latter sex being provided also with strong mandibles. Like the Curculionide, they have no labrum, or upper lip. They are bark-insects, very numerous and varied in the tropics, and displaying great eccentricities of form, but extremely rare in north temperate



LARINUS MACULOSUS.

latitudes, one species only occurring in Europe, in the maritime districts of the Mediterranean. The ANTHRIDÆ have a short and robust rostrum, and long, slender antennæ, terminated by a club of from three to five joints. They are clothed with fine pubescence, variegated with various shades of brown and grey. They differ from Curculionide by the presence of an upper lip. They are lignivorous, with the exception of a limited number, which live on woody boleti on trees. The BRUCHIDÆ are insects of short and broad forms, remarkable for the thickened hind thighs and the inclined head, furnished with a short snout. They are pre-eminently granivorous insects, all the species whose habits are known living—at least, in their larval stage—in seeds. A large number infest cultivated kinds of peas and beans, one (*Bruchus pisi*), being a well-known pest in granaries; its larvæ are so numerous in some years in Germany as to destroy thirty per cent. of the pea crop. The tropical species of the genus *Caryoborus* prefers the nuts of palm-trees, some of which, of stone-like hardness, are not proof against their short, but strong, curved mandibles. Fourteen species of the family are found in Britain. By the structure of their buccal organs they seem to form a connecting link between the Rhynchophora and the other two great divisions of the section Tetramera, the LONGICORNIA and the PHYTOPHAGA.

TRIBE LONGICORNIA.

The numerous tribe of Longicorns, or “long horns”—so called from the great length of antennæ which distinguishes the majority of its constituents—comprises a vast variety of generic and specific forms, conspicuous for the grace and beauty of their outlines and the elegance of their colours and markings, qualities which have rendered them great favourites with collectors. In size they rarely fall below the average dimensions of Coleopterous insects, whilst many of them reach a gigantic length, *Titanus gigas*, of Cayenne and the Amazons, and *Xicuthrus heros*, of the Fiji Islands, reaching half a foot in length, and being amongst the largest of known Beetles. The antennæ, though normally composed of long cylindrical joints, are subject to great diversity in length, shape, and ornamentation, and vary in important details of structure. The usual number of joints is often departed from, species occurring with as many as twenty, and in form they exhibit an endless variety; the joints, generally simple and linear, becoming furrowed or spined on one or both sides, or assuming, some of them a clavate, ovate, or even bulbous form, or branching laterally, giving to the organs a saw-like, pectinate, or fan-like appearance, or, again, presenting ornamental tufts of hair tinted with contrasted colours. The general Longicorn type is, however, preserved amidst all these and other variations.

Like the rest of the Tetramera, the Longicornia are exclusively vegetable feeders, but they are less varied in their food and habits than the Rhynchophora. The perfect insects are met with on the trunks or branches of trees, gnawing the wood or bark, or imbibing sweet sap exuding from wounds in the trees, on leaves and flowers. The larvæ resemble in form those of the Buprestidæ before described, having a dilated prothorax; they are fleshy grubs, provided with three pairs of minute feet, often quite rudimentary, and well-developed maxillary and labial palpi. They live, according to their species, either under the bark of trees or in the interior of the wood, some feeding on roots, but none are known to attack fruit or seeds. Some, however, are often very injurious to fruit-trees, as, for instance, the “apple-tree borer” of the United States, a species of *Saperda*, the larva of which, emerging from an egg laid by the parent insect in the bark, eats its way through to the sap-wood of the tree, where it feeds up, and when half grown farther penetrates to the heart of the tree, living for three years in this stage, and when ready to undergo its transformations returning towards the surface, and passing into the pupa state in a little cell which it forms under the bark. In forest countries, whenever a dead tree is met with, the heart-wood is sure to be found infested with species of Longicornia, often in both the larval and adult conditions. It is thus that many of the large-species belonging to the *Prionine* sub-family are found. In the pine-woods of North America two large species of this group are found in this way, viz., *Orthosoma cylindricum* and *Prionus brevicornis*, the latter of which, like many other insects, has transferred its attentions from indigenous species of trees to the introduced fruit-trees of the orchard, destroying plum and pear-trees and the grape-vine. Upwards of 8,000 species of Longicornia are at present known to science, the forest regions within and near the tropics, as may be supposed, yielding by far the greatest number. Fifty-five only inhabit the British Islands, and the whole of Europe contains only about 500. Notwithstanding the great diversity of their structure, they form but one natural family, the CERAMBYCIDÆ. This



STAG-HORNED LONGICORN (*Acanthoplerus serraticornis*).

is divisible into three sub-families, founded on structural characters, which, though not very sharply defined, form assemblages of genera agreeing in general appearance.

The first, or the *Prioninæ*, are distinguished by the pronotum, or dorsal surface of the prothorax, being separated from the flanks by a sharp edge, and also by the haunches of the anterior pair of legs being elongate and transverse, and lying in similar transverse sockets. The eyes are very generally entire, that is, not notched in front, to make room for the play of the basal joint of the antennæ; but this character is exhibited by many members of the next sub-family. Most of the large and bulky Longicorns with short antennæ belong to the *Prioninæ*. A large number are nocturnal in their habits, and are rarely seen except when flying abroad on sultry evenings, or when the tree-trunks containing them are cleft by the axe of the wood-cutter. These are characterised by the coarseness of the facets into which their eyes are divided, a feature which seems to be associated in some groups of Coleoptera with nocturnal vision. The few species of the sub-family inhabiting north temperate climates belong to this division, such as those constituting the genus *Prionus*, one of which (*P. coriarius*) is found not uncommonly in the southern counties of England, flying abroad in the summer evenings, or seen imbibing the sap from the trunks of old oak-trees in parks. A series of magnificent species of glittering metallic colours, constituting the genus *Psaliognathus*, inhabits exclusively the valleys of the Andes, from South Peru to the Isthmus of Panama. Like several other tropical genera, these are furnished, especially in the male sex, with long toothed mandibles, and present a certain resemblance to the true Stag-beetles, from which, however, they are readily distinguished by their four-jointed tarsi. *Acanthophorus serraticornis*, one of these forms, of very large size, is an inhabitant of Southern India. The most wonderful insect of this group, however, is *Colpoderus forcipatus*, a species discovered by Dr. Pogge in the country of the Muata Yanvo in Central Africa, which is armed with mandibles of excessive length, bent at the middle at a right angle, and each blade strongly forked at the tip. Another section of *Prioninæ* have eyes divided into fine facets, and these are diurnal in their habits. Most of them inhabit tropical America, and are of varied and often metallic coloration. The genus *Mallaspis*, belonging to this section, presents curious modifications in the form of the antennæ, some of the joints being flattened into thin plates and having a metallic lustre.

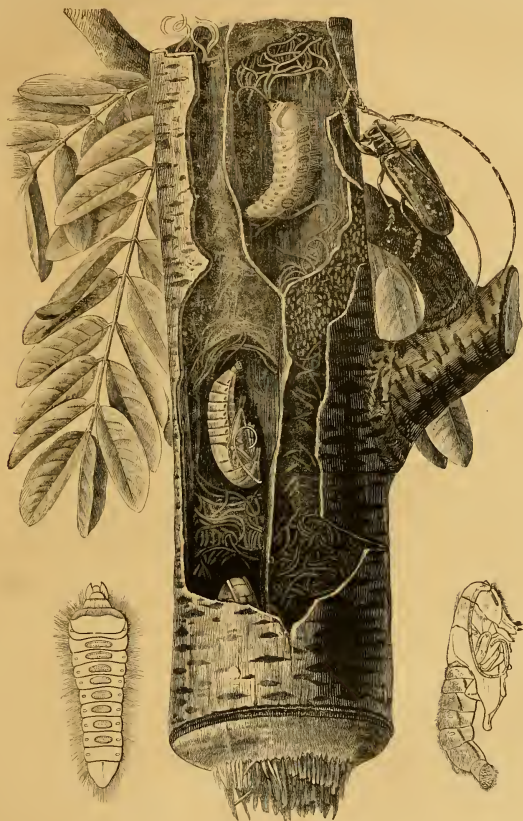
The second sub-family, called *Cerambycinæ*, differ from the *Prioninæ* in the contraction of the sockets of the anterior haunches, the latter being either rounded, or conical and projecting from the sockets, and in the flanks of the prothorax being continuous with the dorsal surface or pronotum. Like the preceding sub-family, they form two natural groups, one nocturnal, with coarsely faceted eyes, and one diurnal, with the same organs smooth and minutely divided. The nocturnal series are usually of dull brown or blackish colours, but the day-fliers are of bright hues, very often brilliantly metallic, and endlessly diversified in the markings with which they are variegated. The variety of colours and patterns is not irregular or capricious, but observes a sort of law, a genus or group of genera having one common type, which is modified, often in a most elegant and artistic manner, in each species. Such is the numerous genus *Clytus*, slender Wasp-like Longicorns, of which there are several species in England, found on flowers and newly-felled timber. Such also are the *Leptura*, a group distinguished by the head being constricted behind into a neck, the species of which, inhabiting chiefly temperate or even high northern latitudes and Alpine regions, are found on flowers. A large proportion of the native British Longicorns belongs to the *Leptura* group, and many may be met with on umbelliferous and composite flowers and wild roses in early summer. *Leptura aurulenta* and *quadrifasciata*, found in the New Forest, are elegant insects of silky dark brown hue, with bands of golden-yellow on the wing-covers.

Amid the great diversity of forms for which this group of Cerambycidæ is remarkable are the genera which mimic Bees, Wasps, and other Hymenoptera. They chiefly frequent tropical America and Australia, and are found on flowers, or flying about tree-trunks, in the same situations as the insects whose forms and colours they have unconsciously been brought to assume, by way of disguise and protection. As a rule, their wing-covers are much shortened, sometimes becoming mere square plates, covering the base of the abdomen, as in the Staphylinidæ: this, apparently, in order to leave the membranous wings exposed, and give them freer play. In some of the species, as *Spekeonmorpha chalybea*, *Odontocera fuscata*, *Tomicopterus larroides*, and others, the abdomen at the base is constricted

into a narrow waist, like the Wasps, thus rendering still more exact their resemblance to the smaller solitary species of that family, to which they are also similar in their light brown and yellow-banded style of colours and markings. Others, in order to resemble deceptively little Bees, have tufts of hairs on their hind shanks, representing the dilated pollen-gathering tibiae of the Bees. These extraordinary little creatures are usually rare in the countries where they are found, and although the species are very numerous, they are not common in collections, and are consequently but little known. Another and very differently coloured set of forms are the *Callichromæ*—Longicorns of large size, and long and graceful forms, coloured golden-green, blue, purple, and violet, furnished with very long antennæ, and much lengthened hind legs, the shanks of which, in some species, have leaf-like expansions. To this group, distributed in many scores of species over the warmer countries of the earth, the well-known British Musk-beetle (*Aromia moschata*) belongs. The early stages of this insect are passed in the trunks and stems of willows, and the perfect insect is common in most parts of England on young willow-branches in osier-beds. It emits a strong odour, slightly musky, of attar of roses, a property which is common to the whole group to which it belongs, and which is much more powerful in some of the exotic species. The volatile secretion producing the smell is emitted by two glands situated in the metathorax of the insect.

The third and last sub-family, the *Lamiinæ*, more numerous, though not more varied, than the *Cerambycinæ*, are almost exclusively confined, in the adult stage, to the branches and trunks of trees, rarely being found on foliage, and never on flowers. In gnawing the bark or wood as food, or in preparing a nidus for the deposition of eggs, they cling to the surface with their generally powerful legs and claws, and their mouths being thus brought into contact with the wood, they ply their mandibles with great ease and precision. In accordance with this habit, their foreheads are vertical and usually at right angles with the longitudinal axis of the body, which is never quite the case with the other sub-families of Longicorns. To this, however, there are exceptions in the numerous remarkable Australasian group of *Tmesisterni*, which, although belonging to the *Lamiinæ*, have oblique foreheads like the *Cerambycinæ*; a more constant character is therefore used to distinguish the sub-family, viz., the existence of an oblique groove on the inner side of the anterior tibiae, which is observable in every species without exception. The prevailing livery of the *Lamiinæ* is a clothing of fine adpressed hairs, coloured in a variegated pattern to resemble bark or wood. In a large number of species the resemblance of the insect in colour and markings to the bark of the particular tree on which it lives is most exact. Such is the case with the Brazilian *Onychocerus scorpio*, and the numerous species of *Acanthoderes*, *Oreodera*, and many others. The huge *Omacantha gigas*, a native of the Gold Coast of Western Africa, resembles a branch with a patch of dark mould on each side. Several genera are composed of long and slender species, having all a streaked patch, of a different colour from the rest of the body, at their tails, so that they imitate with curious exactitude broken twigs, the coloured tip of the body resembling a section of the wood. Some of the genera, however, consist of insects of a brighter style of coloration and markings, and a few shine with metallic lustre. The larger and handsomer species are found chiefly in tropical Africa, and in the Indian and Malayan regions. The last-named zoological province furnishes the gigantic *Batoceæ*, some of which have robust antennæ, nearly a foot in length, and armed with briar-like spines; and in Northern India and Assam occur the *Aristobieæ*, with tessellated orange and black colours and elegantly tufted antennæ. The Mediterranean region furnishes a numerous wingless group (*Dorcadion*), found only on the ground amongst herbage, the larvæ feeding on roots. In the forests of North and South America a set of species are found, of nearly cylindrical form, which have the singular habit of gnawing branches of trees all round, to a depth sufficient to cause the bough to break and fall to the ground. These form the genus *Oncideres*, belonging to a numerous group distinguished by their elongated forms, strong and frequently bowed legs, and powerful claws adapted for grasping. The insect selects a branch or bough suitable for its purpose, and, embracing it tightly, proceeds to gnaw the bark and wood transversely, and so effective a workman is he that the ring-like notch when finished is as true as if turned in a lathe. The object of this singular trait of industry is in all probability to provide a supply of dead wood for the nourishment of the future progeny. Branches thus neatly sawn off are frequently met with in tropical American woods, and are the objects of wonder to the negroes and creoles, who erroneously suppose them to be the work of *horned*

Dynastidae, or (in some districts) Stag-beetles. They say the large, heavy-bodied Beetle—in the West Indies the Elephant-beetle (*Dynastes Hercules*) is the supposed operator—seizes the branch between



ONCIDERES VOMICOSUS.

its two long horns (one projecting from the crown of the head and the other from the thorax), and setting itself in rapid rotatory motion, continues until the branch is sawn through. But the horns or jaws of these large Beetles are quite incapable of the work thus attributed to them; and, in fact, the

story is a pure myth. The point has been settled by direct observation. A not uncommon North American species (*Oncideres cingulatus*), called the "Hickory girdler," is known to saw branches of the hickory-tree (*Carya alba*) in the manner we have described, and its habits have been carefully studied by Professor Haldeman. Our figure represents a larger species (*Oncideres vomicosus*) not uncommon in Brazil.

TRIBE PHYTOPHAGA.

The Phytophaga, the third and last tribe of the great Tetramerous division, are, as a rule, distinguishable from the Longicornia (with which they agree in the absence of the snout-like prolongation of the head which characterises the Rhynchophora) by the shorter body and antennæ, and the brightly-coloured and polished integuments. In habits they differ by living only on the foliage of plants, not on the wood or fruit; and they are, with the exception of one genus (*Cyrtous*), diurnal in their period of activity, having in consequence finely-faceted eyes. So close, however, is their relationship to the Longicornia, that there is no single structural character to be pointed out as applicable in all cases for distinguishing the two tribes. In nearly all the species the tarsi are short and broad, with the third joint bi-lobed or heart-shaped, and the rudimentary or functionless fourth joint always visible at the base of the claw-joint; beneath, the joints 1—3 are furnished with flat brush-like palpi, which enable the insects to walk with ease, even back downward, on the under surface of leaves; and the claws are very often adapted for clinging to the edges of foliage, either by their position, or by being more or less toothed on their inner sides.

Although so closely allied in structure in the adult form, the Longicorns and the Phytophaga are strongly contrasted in their larva stage. The larvæ of the Phytophaga are nearly always of short and convex form of body, rarely sub-cylindrical or depressed, and of firm leathery texture, sometimes metallic-coloured like the perfect insects. Their abdominal segments are frequently provided with fleshy or scaly tubercles, or spines and bristles, and the anal one is prolonged beneath into a retractile tube, which is used in walking. In all cases they live on the same food, and generally on the same species of tree or shrub, as the perfect insect. On the same plant the eggs are laid, and in numerous cases, where the species infest cultivated grounds, their great and rapid multiplication during the summer months renders them the most injurious of all insect pests to the farmer and gardener. The famous Colorado Potato-beetle, which increased so suddenly, and created such devastation in the United States a few years ago, and seemed likely to cross the Atlantic, to the alarm of the agriculturists of Western Europe, belongs to the family, as does also the "Turnip-jack," the plague of the British farmer. One numerous class of the larvæ (belonging to the Hispinæ and Halticinæ sub-families) are miners, *i.e.*, they live within the cuticles of leaves, devouring the parenchyma, and undergoing their transformations in the same confined space. Another large group (belonging to the sub-families *Criocerinæ* and *Cassidinæ*) live exposed on leaves, and have the remarkable habit of concealing themselves with their own excrement, which is retained and secured by a special horny apparatus at the end of their bodies. In the typical groups of *Chrysomelinæ* and *Eumolpinæ*, the larvæ feed at large on plants, and bury themselves in the earth previous to changing into the pupa stage.

The Phytophaga are divided into four sections, which are nearly equivalent to the families of other tribes. The first of these, the ERPODA, approach nearest in their general form, as well as in their structural characters, to the Longicornia and the family Bruchidæ of the Rhynchophora. Among them are the large brilliantly-metallic *Sagra*, or Kangaroo-beetles of tropical Asia and Africa, remarkable for their greatly-enlarged hind legs; the *Donacia*, elegant insects of similar form, but smaller and of less brilliant colours, which live on water-lilies and other aquatic plants chiefly in north temperate climates, nineteen species being found in the British Islands. They pass their early stages amongst the roots of the same plants; and the *Criocerinæ*, of which there are several British species—the principal being *Crioceris merdigera*, of uniform brownish tint—parasitic on lilies, and the prettily-spotted *C. asparagi*, found abundantly on asparagus plants in the south of England. The second section are the CAMPTOSOME, characterised by the strong curvature of the ventral segments of the abdomen, by which the three middle ones are much contracted. To this belongs a large series of genera, having usually a compact oval or oblong form of body, and extremely varied colours, polished metallic coloration being less the rule than buff, yellow, and red, spotted or striped with darker hues. The British species best known of this section are the *Clythra tridentata* and

quadripunctata found in oak and hazel woods, and the brilliant golden-green *Cryptocephali*, common on flowers of hawkweed on dry banks in the month of June. The third section are the CYCLICA, and consist of those genera in which the abdominal segments are of normal proportions, and the antennæ are filiform. The typical genus is *Chrysomela*, which, with its various closely-allied sub-genera, is distributed in many hundreds of species over all the temperate and tropical parts of the earth. Its species, as a rule, are of polished metallic colours, some, like the *C. cerealis*, a British species found on Snowdon, of golden or brassy-green ground colour, with rich purple stripes; others equally brilliant, but of more uniform metallic hues, such as *C. menthastri*, a large brassy-green kind, found on aquatic plants, *C. polita* and *C. staphylea*, abundant on nettles in spring, and the bronzed and punctured *C. banksii*, met with on sandy banks on the southern coasts of England. *Lina populi*,



CRIOCEIS MERDIGERA.

closely allied to the true *Chrysomelæ*, is a well-known British species, found on poplars. As is the rule with the Phytophaga of northern climates, a few individuals of the late summer brood of these *Chrysomelæ* pass the winter in the adult stage in a dormant state in moss, becoming the parents of the spring broods in the following year.

The sub-family *Chrysomelinæ*, to which the above-mentioned species belong, contains most of the large and conspicuous insects of the section; but it is far exceeded in the number of its genera and species by the *Galerucina*, a sub-family which includes all the *Halticidæ*, or jumping Phytophaga, insects usually of very small size, and almost infinite in their numbers and diversity. The *Galerucina* may be readily distinguished from the *Chrysomelinæ* by the antennæ being inserted near together in the middle of the forehead, these organs in the *Chrysomelinæ* being situated near the inner margin of the eyes, and therefore widely distant from each other. The *ambulatorial Galerucina* are, as a rule, of larger size than the *saltatorial* division of the sub-family (the *Halticidæ*), and are insects of rather slow movements. Many species occur in the British Islands; some (*Galeruca tanacetii*, *coprea*, and *hulensis*) are met with abundantly on heaths and uncultivated grassy hills and slopes, crawling over the low herbage; others are found only on trees. The *Halticidæ*, as we have already stated, are—at least, partly—leaf-miners in their early stages, and include the Turnip-fly (*Phyllotreta nemorum*), and many

other allied species destructive to cruciferous plants. In temperate latitudes none but species of small and even minute size are met with, the latter resembling fleas in their dimensions and great agility in leaping; but in the tropics much larger and more brightly-coloured and variegated forms swarm on bushes and herbaceous vegetation. The fourth and last section are the *CRYPTOSTOME*, distinguished by the forehead being inflected downwards, bringing the mouth (which is much reduced in all its dimensions) to the under surface of the head, and also by the claw-joint of the tarsi scarcely projecting beyond the lobes of the third joint. The antennæ are short, and very often straight and rigid. To this section belong two sub-families, *Hispina* and *Cassidina*, which run into eccentric and striking forms, the thorax and elytra of the *Hispina*, in their extreme developments, being studded with spines, and the same parts in the *Cassidina* being laterally expanded, so as to cover the head and trunk as



LINA POPULI.

with a rounded shield. These extreme forms are placed naturally by all entomologists who have classified the groups at the end of the two respective sub-families, so that the classification in each begins with species which partake of the characters of both, and is carried on through the very numerous genera and species, pretty gradually receding on each hand from the common type. Thirteen species of the genus *Cassida* are met with in England, two of which are not uncommon on thistles in summer, on which plants the curious habits of the larvæ may be studied, protected as they feed by a little mass of their own excrement, secured by a horny forked process at their tails. Some of the native British species of *Cassida* are ornamented with bright silvery streaks or markings, which, however, give but a faint idea of the extreme brilliancy of many tropical ones, some of which resemble beads of polished gold or silver, and others, of more pearly lustre, glitter on the leaves like drops of dew in the morning sun.

TRIBE EROTYLIDES.

This group differs from the preceding in many important characters, and belongs but imperfectly to the *Tetramera* section, many of its genera having a conspicuous fourth joint to the tarsi, and the antennæ being terminated by a distinct club, as in the more typical genera of the *Clavicornia* tribe. All the species, upwards of 1,000 in number, live on fungi or boleti, and have smooth integu-

ments and bright colours, in which red, yellow, and black hues prevail, forming often elegant patterns on the wing-covers. The larvæ are elongated, of leathery texture, slightly narrowed at the two extremities, the head furnished with three-jointed antennæ and ocelli on each side, and the thorax with three pairs of feet of normal development. In their structure they point to a relationship with the family Coccinellide. The transformations of the larger exotic species are up to the present unrecorded; but the *Erotylus hopei*, which the present writer had the opportunity of observing in South America, seems to differ a little from the European species (genus *Triplax*), in being studded with longish spines, and the anal segment furnished with a pair of very long setiform appendages. The prothoracic segment is larger than the others, and nearly semicircular. These larvæ were found abundantly on hard boleti on an old stump, and underwent their transformations attached by the tail to leaves, precisely like the Lady-birds (*Coccinellæ*). The tribe is generally considered as a natural family, and is divided into three sub-families: *Languriinæ* (extremely narrow and elongate forms, with broadly dilated tarsi, of which there are no European species), *Helotinæ* (handsomely sculptured and metallic species, inhabiting tropical Asia and Africa), and the typical group *Erotylinæ*, comprising the great bulk of the species, and distributed over all temperate and tropical regions. The Erotylinæ of the Old World are of elongated oblong form, but those of America are in great part dilated, ovate, or with elytra expanded and raised into huge domed-like bosses.

SECTION TRIMERA.

In this section the tarsi have only three true joints, the joint which is apparently the analogue of the third in the Pentamera being rudimentary at the base of the claw-joint, just as the fourth



COCCINELLA SEPTEMPUNCTATA (SEVEN-SPOTTED LADY-BIRD).

is in the Tetramera. The section is divided into two families, *Endomychide* and *Coccinellide*, which each contain only one genus.

FAMILY ENDOMYCHIDE.

The insects of this family differ from the COCCINELLIDÆ chiefly in their much longer and more robust antennæ, which are generally half the length of the body, never retractile under the head and breast, and terminated by a distinct club of three joints; they are also distinguished by their long legs and by their pronotum being furnished behind with two well-marked grooves. The species live on fungi and boleti, chiefly the smaller growths which affect rotting timber, and reach their greatest development in size, beauty of markings, and strangeness of form in the tropical regions of the eastern hemisphere. About 400 species have been described, two only of which inhabit the British Islands. The larger species, inhabiting India and the islands of the Malayan Archipelago, assume eccentric shapes, the elytra being greatly dilated along the margins and elevated into bosses on the disc, often armed with spines. In many respects these species may be said to represent the similarly-formed *Erotgli* of the same latitudes in the New World. Both perform the same functions in the natural economy of their respective countries; and in each of the two regions the one has been developed apparently at the expense of the other, since none but ordinary forms of Endomychidæ exist in Tropical America, and none but similarly undeveloped forms of Erotylidæ are found in Tropical Asia.

FAMILY COCCINELLIDÆ.

The COCCINELLIDÆ are the familiar insects known under the name of Lady-birds, the great majority of which in all countries have the hemispherical form and prettily-spotted colours that distinguish our common species. Some of the genera, of oblong shape of body, and others, in which the surface is clothed with short hairs, and the colours darker and less varied, may at first sight not be recognisable as belonging to the family; but in such cases they may be known by their three-jointed tarsi, hatchet-shaped terminal joint of the maxillary palpi, and the very short antennæ retractile beneath the prothorax. Nearly the whole family have the peculiar habit of preying on Aphides, or plant-lice, one group only, containing a small number of genera, being leaf-eaters. The larvæ, which are seen in our gardens and fields even more abundantly than the perfect insects, and devour immense quantities of Aphides, are of long oval shape, narrowed behind, with integuments of solid or leathery consistence, and generally dark-coloured; they have six legs, and have considerable freedom and quickness of motion, resembling miniature Lizards somewhat in their gait and attitude; they change into the pupa state on leaves and other objects in the vicinity of Aphis-infested plants, gluing first their tails to the surface. The perfect insect emerges in a few days in the usual way, by a rent in the skin of the pupa, and thus the generations continue whilst the summer lasts. In the late autumn the few surviving adults crawl into sheltered nooks under the loose bark of trees, or in warm mossy banks, and become dormant for the winter. In some summers our common species (*C. septempunctata*) multiplies to a prodigious extent, and the swarms which cover hedges and trees attract the attention of even the most unobservant. The largest swarms on such occasions are to be seen on the southern or eastern coasts of England, and in some years innumerable individuals have been found drowned on the surface of the sea or cast by the waves on the shore. Upwards of 1,500 species of Coccinellidæ have been described from various parts of the world, of which forty only have been found to occur in the British Islands.

HENRY WALTER BATES.

CHAPTER VI.

ORDER HYMENOPTERA:—ACULEATA, OR STINGING HYMENOPTERA.

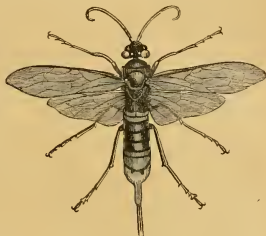
Characters—The Prothorax—The Membranous Wings—The Ovipositor, or "Sting"—Internal Structure—Habits—Larvæ—Intelligence of the Hymenoptera—Their Social Organisation—Workers, or "Neuters"—The Sexes—The Humming of the Bee—Species of Hymenoptera—Fossil Remains—Classification—ACULEATA, OR STINGING HYMENOPTERA—APILARLE, or BEES—Characters—THE HIVE BEE—The "Hive"—Arrangement of Cells—Intelligence evinced by the Bees—The Secretion of Wax—Construction of the Cells—Deposition of Eggs—Transformations of the Bee—The Workers—Bees in Winter—The "Royal" Cell—Swarming—Formation of a New Hive—Behaviour of the Young Queen—The Cases of Limited Fertility—HUMBLE BEES—Habits—*Apachus vestalis*—The Solitary Bees—THE VIOLET CARPENTER BEE—Gnawing-out and Excavation of the Nest—THE MASON BEE—Its Cell—The Genus *Osmia*—The Leaf cutting Bees—The Cuckoo Bees—The *Andrenidae*—VESPILE, or WASPS—Characters—Cells—Beauty of Workmanship—Mr. F. Smith's Account of the Founders of a Wasp Colony—Nests of the Common Wasp and of the Hornet—The Nests of other Species—The Solitary Wasps—The Wall Wasp—THE CRABRONIDE—The Sand Wasps—THE POMPILIDE—THE SAFYRIDÆ—THE MUTILLIDÆ—THE FORMICIDÆ, OR ANTS—Characters—The Nests—The Metamorphosis—The Workers—Milking the Aphides—Charge of the Young—Habits—Intelligence—The Wood Ant—Other Species—THE CHRYSIDIDÆ, OR GOLDEN WASPS.

THE Hymenoptera, which we have placed as the second order of insects with a complete metamorphosis, differ in many important respects from the Coleoptera. Perhaps the most striking external distinction is to be found in the structure of the wings, both pairs of which are membranous, as indicated in the name given to the order by Linnaeus, which must be taken to signify "membrane-winged," although, as will be seen hereafter, this texture of the wings is by no means peculiar to the Hymenoptera; and another peculiarity of equal importance, although less immediately obvious, is the condition of the prothorax, which, instead of forming a comparatively large piece, moving freely in front of the other two segments of the thorax, is reduced to a sort of ring, and firmly attached to the succeeding segments, either by a great part of its hinder surface or at least by the upper portion. This reduced prothorax is often called the *collar*, and its condition in the Hymenoptera may be regarded as indicating a certain degree of relationship to the haustellate orders of the Metabola, the Lepidoptera, and Diptera. In the Bees, which belong to the present order, the parts of the mouth undergo modifications tending in a similar direction.

In general, the Hymenoptera may be described as four-winged Flies, having the head very freely attached to the thorax, the prothorax reduced, and attached to the mesothorax as just described; the other two thoracic segments very closely amalgamated (although in one great group this character is not presented); the abdomen ovate, elliptical, or much elongated, composed of segments, the hinder margins of which overlap the base of the succeeding segments, while the lateral margins of the dorsal plates in like manner overlap those of the ventral plates. This arrangement gives great freedom of expansion in respiration, and the movements of the abdomen for the performance of this function are generally more conspicuous in the Hymenoptera than in any other insects. The female is nearly always provided with a sting or an ovipositor issuing from the abdomen.

The head, which is joined to the thorax by a thin neck, bears on its upper surface a pair of antennæ, a pair of compound eyes, usually of considerable size, and sometimes very large, and three simple eyes, or ocelli (see Fig. 4, p. 284). Of these organs the antennæ alone need to have a few words said of them. They are frequently long organs, composed of a number of similar joints, and either quite thread-like, or tapering, or clubbed towards the end; but in certain families they consist of a long basal joint (called the *scape*), followed by a comparatively small number of shorter joints, forming a sort of lash, which is generally bent at an angle to the first joint. Such antennæ are called geniculate (see Fig. 5, B, p. 284).

Of the parts of the mouth, the mandibles are always freely articulated and adapted for biting purposes, but the other organs may undergo considerable modifications. In general, they present the ordinary structure of the biting mouth, but their articulation is usually very free, enabling them to be

TAILED WASP (*Sirex gigas*).

protruded more or less; the lobes of the maxillæ are generally fused together; the mentum is small, and the ligula usually furnished with side lobes (*paraglossæ*). In the Bees, as already noticed (p. 286), the ligula and maxillæ are much elongated to form the proboscis.

The two pairs of membranous wings are attached to the upper part of the sides of the meso- and metathorax, and above the base of each fore wing there is a small movable plate (*tegula*), which is regarded as forming part of the episternum. The surface of the wings is naked or furnished with scattered hairs, and the membrane of which they are composed is usually more or less transparent, although in some cases it may be dark-coloured. In certain forms belonging to the order the wings are altogether absent, or they may be present in one sex and wanting in the other, or, as in the whole tribe of Ants, there may be no wings in the workers (or infertile females), while the perfect males and females possess them; but where they exist the fore wings are almost invariably larger than the posterior pair. All four wings are used in flight; during repose they are generally laid together over the back of the insect; when in action the hind wings are held fast to the fore wings by means of a row of minute hooklets placed along part of their front margin, which cling to a small groove at the posterior edge of the front wings. This mode of union of the wings is characteristic of the Hymenoptera; and many years ago an entomologist maintained that this rather than the membranous texture of the wings, which occurs in other orders of insects, had suggested to Linnæus the name given to the present order, the wings being, as he said, in a manner *married* to each other.

The arrangement of the horny veins (*see* p. 283) which traverse and stiffen these membranous wings is also generally very characteristic. In some few instances they are reduced to a minimum, but in most there run from the base of the fore wings certain longitudinal veins, at first nearly straight, but afterwards more or less bent or waved, and then united by cross-veins in such a manner as to enclose a few angular spaces on the disc of the wing. These spaces are known as *cells*, and their number, arrangement, and form furnish important characters for the classification and



DIAGRAM OF HYMENOPTEROUS WING.

description of the Hymenoptera. In the fore wing (*see* figure) we find along the front margin a strong marginal vein (*costa*), with another longitudinal vein parallel and very close to it (the *subcostal vein*), and the two unite beyond the middle of the front margin to form a horny swelling (the *stigma*). From this a small vein generally runs towards the extreme tip of the wing, cutting off a portion of the surface, which is called the *radial cell*, and may be divided into two or more by cross-veins. Another vein, which runs along the middle of the wing from the base, and is continued in a more or less bent or undulated fashion towards the apex of the wing, gives off a branch, which runs up to join the subcostal vein, and also gives off a branch, the space enclosed between which and the stigma and radial vein is divided by a greater or less number of cross-veins into cells, called the *submarginal cells*. Other cross-veins (known as *recurrent veins*) run back from these cells to the original main vein, enclosing spaces known as *discoidal cells*. The veining of the hind wings is much more simple, and of little or no systematic importance.

The legs in the Hymenoptera possess great freedom of motion. They are articulated to the thoracic segments by very large, projecting, more or less conical hip-joints (*coxae*), to which the thighs are attached by means of ring-like trochanters, which, in a great number of the species, are composed of two joints. The tarsi are almost always of five joints, of which the first is generally considerably longer than the rest, and often very different in form.

The number of segments in the abdomen varies considerably, but not more than eight or nine are recognisable, the remainder being either suppressed or concealed within the others. In some forms the abdomen is attached to the thorax by the whole breadth of its base, but in the great majority the first or first and second segments are contracted so as to form a slender stalk, by which the union with the thorax is effected (*see* figure on p. 355). According to some anatomists, the hindmost part of the thoracic mass, which bears a pair of stigmata, does not really belong to the thorax, but constitutes the first segment of the abdomen: this, however, is a question upon which we need not enter. The mode of union of the segments of the abdomen, and the relation of their dorsal and ventral plates, has been already alluded to.

The females of nearly all the species of this order possess organs, either projecting or protrusible

from the apex of the abdomen, which subserve the purpose of conveying the eggs to the spot where their development is to take place, and at the same time, in many instances, constitute formidable offensive weapons. These are the ovipositors, or stings, the parts composing which must be regarded as appendages of the concealed terminal segments of the abdomen. The latter are represented by movable plates, to which the main piece of the protrusible organ is attached, and also furnish sheathing-pieces, often of considerable length, which seem to serve as supports to the latter during the act of penetration. In the great majority of the Hymenoptera the ovipositor, or sting, consists of a single middle principal piece, deeply grooved along its lower surface, and of a pair of slender lancets, which rest against the edges of the middle piece and against each other in the middle line, so as to close up the groove in the single piece, and convert it into a canal. With this canal the oviducts are connected at the base of the organ, so that when its point has been forced a sufficient distance into the proper nidus for the development of the young, the eggs can readily pass to their destination. In the case of those insects in which the organ is converted into a sting, all the parts are exceedingly acute, and the base of the organ is put in communication with a peculiar gland

COMMON WASP (*Vespa vulgaris*).

LARVA OF SAW-FLY.

secreting an acrid fluid, which contains much formic acid, and it is the injection of this fluid into the puncture produced by the sting that makes the effects of being stung by a Bee or a Wasp so exceedingly painful. The stings of these animals are not, however, to be regarded as exclusively intended as weapons of war. A very great number of them require to provide their young with a supply of animal food, which consists generally either of the larvæ of other insects or of Spiders. To render these victims helpless and incapable of making their escape, the mother stings them before depositing them with her egg in the nest she has prepared, and by this means they are paralysed, although they can still live for a considerable time. The larva kills them as he wants them, and thus a supply of fresh provisions is secured for him during the whole course of his development. The above may be taken as a general description of the character of the ovipositor in the great

majority of the Hymenoptera. It is departed from only in one family, that of the Saw-flies (*Tenthredinidae*), as will be noticed in the character of that group.

Of the internal structure of the Hymenoptera we need not say much, but there are certain peculiarities which should be noticed. The alimentary canal is generally of moderate length; the malpighian vessels are short and numerous; salivary glands, opening into the mouth, occur in most species, and attain a particularly large development in those which have to build cells for the rearing of their larvæ; and the two hinder ganglia of the thorax are united into a single mass, while the ventral chain usually has five or six ganglia. A structural character connected with the great power of flight generally possessed by these insects is the great enlargement of main tracheal stems, which are dilated in the abdomen into very large air-sacs.

In their habits the Hymenoptera are diurnal, most of them flying about actively in the hottest sunshine in search of the flowers upon the sweet juices of which they chiefly live in the perfect state. The working Ants and the females after their nuptial flights, and some few species of other families, are destitute of wings, and can only crawl upon the ground or on plants; but these are active during the day like their more favoured relatives, and the Ants usually retire into their nests and shut themselves up there when night comes on.

In the habits of the larvæ there is great diversity, notwithstanding great general uniformity of structure. Except in one division of the order, the larvæ of these insects are soft, footless creatures, which would be called maggots but for their possessing a hard, horny head. In the Saw-flies and Tailed Wasps, which differ in several important particulars from the rest of the order, the larvæ generally resemble Caterpillars (see figure above), possessing three pairs of thoracic limbs, more or less developed; and in the case of the greater number, whose larvæ feed openly upon the leaves of plants, also several pairs of abdominal pro-legs. The maggot-like grubs (see figure on p. 356), which always live

in concealment, have nevertheless a great diversity of needs in the matter of food. Some, like the Bees, feed upon the honey and pollen of flowers; the larvæ of the Gall-flies also live upon vegetable food, which is furnished to them by the tissue of the singular excrescences (galls) produced upon trees and plants when punctured by the ovipositors of the parent insects. Of the rest, the larvæ for the most part prefer animal food, at least as a portion of their diet, but the form in which they obtain it differs very considerably. To some nothing seems to come amiss, but the majority are more or less limited as to the kind of food that suits them. The larvæ of other insects and spiders are the chief sources of supply; but the mother may either collect these more or less indiscriminately, or select the individuals of a single species for the maintenance of her progeny. Further, besides all these cases of larvæ residing in cells and fed with various



LARVA, NYMPH, AND COCOON OF WOOD ANT (Natural Size and Magnified).

articles collected for them, we find among the Hymenoptera a vast number of examples of parasitism, the females depositing their eggs upon or in the body of some other insect, which then serves as the food of the larvæ. The phenomena of parasitism are here displayed under almost every possible variety of circumstances: the insect attacked may be in any stage of its existence, from the egg to the imago; the parasites may occur singly or several together, and their emergence may take place at very different periods in the life of their victims; but in all cases, except that of the parasites in eggs, their functions would seem to be to allow the host to live and perform its individual part in the world, but to prevent its leaving any progeny behind it. Speaking generally, this would seem to be the most important function of parasitism in nature, and it is shown very strikingly by the internal insect-parasites.

The larvæ of the Hymenoptera are provided with silk-glands opening near the mouth, and by means of the secretion produced by these organs they are able to spin a cocoon for their protection during the pupa state. The larvæ generally remain for a considerable time apparently unaltered within the cocoon, and become converted into pupæ only at a period comparatively near that of their emergence as perfect insects. The pupa has all its limbs and other external organs separately encased and quite distinct from each other and from the body (see figure above).

The Hymenoptera present the highest development of the mental qualities, whether they are to be regarded as instinctive or as representing absolute intellectual activity, that we meet with anywhere in the class of insects, or indeed among Invertebrate animals in general. It is in providing for the well-being of their progeny more especially that they display these qualities most brilliantly; and although most of their actions in this direction may doubtless be referred to those inherited mental operations which we usually denominate instinct, cases are not wanting in which, in the presence of exceptional circumstances, these little creatures manifestly reason upon the novel position in which they are placed, and adopt such modifications of their ordinary procedure as may be rendered necessary.

These intellectual characteristics, which give the Hymenoptera a pre-eminence over all other insects are specially manifested in connection with another peculiarity, namely, the complex social mode of life of a considerable number of the species. The extraordinary polity of the Bees, Ants, and Wasps, which has excited the wonder and admiration of mankind in all ages, is only partially paralleled elsewhere by the so-called White Ants (Termites), which belong to the Orthopterous order; and although the proceedings of the latter are sufficiently interesting, they yield in many respects to the social Hymenoptera. Fundamentally, the extraordinary social organisation observable in Bees, Ants, and Wasps is connected with the care of the young, an object which appears to exercise a primary influence upon the habits of many other Hymenoptera which do not live in societies. It consists not only in the living together in nests of various construction of a greater or less number of individual insects, all of whom co-operate in carrying on the business of the community, but, further, in the modification of certain individuals to fit them for the performance

of particular offices, so that a society of Hymenoptera is composed of at least three kinds of adult individuals, namely, perfect females, males (whose presence in the nest is only temporary), and workers, or neuters, as they are sometimes called, the last-named having upon their hands the chief part, if not the whole, of the business of the construction and defence of the nest, bringing in supplies of provisions, and rearing the young. The term neuters applied to them is, however, a misnomer; an examination of their anatomy proves them to be imperfectly-developed females, generally quite incapable of producing eggs, and always incapable of being fertilised. Thus these societies are to be regarded as including males for a short time, and at least two kinds of females, namely, true fertile females, whose chief duty is the production of eggs, and infertile females, which take up the other feminine duties of attending to the domestic economy, and especially to the nursing of the young. It is known, chiefly from the study of the Hive Bee, that the eggs laid by the female are of only two kinds, male and female eggs, and that the development of the larvæ from the latter into fertile or infertile females is due to differences in the food administered to them; in fact, when a hive of Bees loses its queen, or fertile female, the surviving workers are able to replace their sovereign by administering the so-called "royal food" to a female larva, which would otherwise have produced a worker, the only condition necessary being that the larva selected for this honour should be very young. Further, it is a well-established fact that occasionally some of the workers—probably owing to their larvæ having accidentally received a portion of "royal food"—acquire a slightly-increased development of the ovaries, and produce eggs, a conclusive proof of their sex.

These facts have been pretty generally known for a great many years, but certain questions arose out of them which were by no means easy to settle, although they may be all referred to the one primary question—at what period is difference of sex established in the progeny of these insects? Does this difference exist already in the egg? or is it set up subsequently by difference of treatment of the larvæ, just as the worker larva may be developed into a queen? This difficult point was settled by the observations of a German pastor, named Dzierzon, who originated a theory, afterwards further developed by the distinguished zoologist, Von Siebold, and now generally accepted, which seems to explain satisfactorily all the phenomena of reproduction as exhibited in Bees.

It has already been stated (p. 294) that in insects the eggs are fertilised during their passage through the oviduct by contact with the male fertilising element, which has been stored up in a special receptacle appended to that passage. Dzierzon found that the eggs laid by very old queens, in which the fertilising element was exhausted, by queens which, from having crippled wings, were unable to take the customary nuptial flight, and by workers which, from their structure, were incapable of being fertilised, always produced males or drones; and hence he inferred that the difference of sex was established at the moment of the deposition of the egg, those eggs destined to produce females or workers being fertilised during their passage through the oviduct, while those which were to furnish males were allowed to pass without fecundation. Subsequent investigations, carried on by Von Siebold, Leuckart, and others, fully confirmed this opinion. Fertilised queens were converted into drone-breeders by exposure to considerable cold, and by the mechanical destruction of the special receptacle above mentioned; and the examination of eggs laid by fertilised queens showed the presence of the fertilising filaments in those intended to produce workers, while no such elements could be detected in those laid in drone-cells. The occurrence of the same phenomena has been demonstrated in the case of other social Hymenopterous insects, and may safely be assumed for all, although of course their demonstration is attended with much greater difficulty in the other species than in the Hive Bee. By what means the female contrives, apparently at will, to fertilise the eggs, or leave them unfecundated, has not yet been ascertained, nor is it very clear how she knows when fertilisation is necessary or unnecessary, except that in the case of the Hive Bee, and perhaps of some Wasps, the different sizes of the cells prepared for rearing males and workers may furnish indications.

Very few of the Hymenoptera seem to possess special arrangements for producing sounds by the friction of one part against another, but many of them, especially Bees and Wasps, produce a humming or buzzing noise, principally during flight. The sound emitted appears to be due to two causes—first, the rapid vibration of the wings in the air, which of course can only be perceived during flight; and, secondly, according to Landois, to the vibration of certain chitinous plates, placed in the orifices

of some of the stigmata, caused by the violent expulsion of the air from the tracheal system. With regard to this second set of sounds, however, a French observer, M. Pérey, comes to a different conclusion, and declares that the removal of the above-mentioned scaly parts, or even the absolute stopping of the stigmata, does not prevent the buzzing, which he believes to proceed from the friction of the bases of the wings upon the solid parts surrounding them.

The Hymenoptera are for the most part of small or moderate size, few species exceeding two inches in length, or three in expanse of wings. A great number, especially of the parasitic forms, are exceedingly minute. They appear to be very generally diffused over the surface of the earth, but are probably more numerous in the warmer regions than in temperate zones. The number of described species is estimated at about 16,000, but this must bear only a very small proportion to the total Hymenopterous population of the globe. It has been estimated that we have about 3,000 species in Britain, and, making every allowance for the probable exaggeration of this estimate, owing to comparative want of thorough knowledge, we may believe that the number of species of Hymenoptera does not fall very far short of that of the Beetles in the British area; and, extending the argument to a wider field, it may be assumed that the Hymenoptera of the whole world are not much less numerous than the Beetles.

Geologically the Hymenoptera are not very ancient. Professor Heer has described a fragment of a wing from the Lias of Schambelen, in Switzerland, as possibly belonging to a species of Ant; but he is very doubtful whether it represents a Hymenopterous insect at all, and an inspection of his figure will show that his doubts are very well founded. Several species have been described as occurring in the Lithographic limestone of Solenhofen, in Bavaria, which belongs to the Upper Oolite; but these are regarded as doubtful by good authorities, and it is not until we reach the Tertiaries that unmistakable remains of Hymenopterous insects are met with. Here, however, they occur in all the deposits in which fossil insects are found, and are generally so nearly allied to existing types that they may safely be referred to the same families, and often to the same genera.

The classification of the Hymenoptera has undergone some superficial changes, although the views of entomologists as to the relations of the families have generally remained much the same. Latreille divided them into Aculeate and Terebrant Hymenoptera, according as the females were provided with stings or ovipositors, and the second group into Pupivora, with the abdomen attached to the thorax by a narrow part, and Securiæ, in which the union of these two parts of the body is by the whole width of their bases. This arrangement was very generally followed for many years, and it seemed to be confirmed by the observation that throughout the whole of the Terebrantia of Latreille the trochanter consists of two rings, whilst in the Aculeata there is only one. The differences between the two great divisions of the Terebrantia are, however, so great and important, and the resemblances of the second of them to the Aculeata are so striking, that of late several leading authorities have adopted a triple division of the order, in which all the broad peculiarities of the insects are duly taken into consideration. This arrangement we shall adopt here, as it seems to enable all the affinities of the different families to be shown most distinctly. The three great tribes, or sub-orders, thus arrived at are as follows:—

I. ACULEATA: having the trochanters simple; the abdomen attached to the thorax by a narrow part; the females provided with a retractile sting connected with a poison-gland; and the antennæ with twelve joints in the females and thirteen in the males. The larvæ are footless grubs, with no posterior aperture to the intestine.

II. ENTOMOPHAGA: having the trochanters composed of two rings; the abdomen as in the preceding; the females provided with an ovipositor, which usually projects from the body, and is enclosed by a sheath formed by two valves; and the antennæ with a variable and often very large number of joints. The larvæ are like those of the preceding group.

III. PHYTOPHAGA: the trochanters of two rings; the abdomen attached to the thorax by the whole width of its base; the ovipositor either a saw-like organ consisting of two valves, or an ovipositor nearly agreeing in structure with that of the preceding group; antennæ generally with a moderate number of joints. The larvæ are vegetable feeders, usually resembling Caterpillars, having six more or less developed thoracic legs, and generally a number of pro-legs on the abdominal segments; their alimentary canal has an anal orifice.

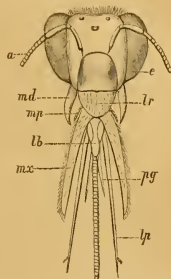
TRIBE I.—ACULEATA.

FAMILY APIARIE, OR BEES.

THE chief characteristic of this family is to be found in the structure of the mouth, in which, as already described (p. 286), while the horny mandibles serve as biting organs, the labium is more or less elongated, as are also the maxillæ, the lobes of which are flattened like thin blades, which embrace the elongated ligula, the whole forming a sort of proboscis or tongue by means of which the insects suck or lap up the nectar of flowers. The ligula usually bears paraglossæ; the labium has four-jointed palpi; and the maxillary palpi have from one to six joints. The antennæ are more or less geniculate (Fig. 5, B, p. 284); in the males they are usually longer than in the females, and consist of thirteen joints, those of the females having only twelve. The eyes have the front margin entire; the vertex bears three ocelli; the wings, which have two or three sub-marginal cells, are not folded longitudinally in repose; and the posterior tibiæ and first tarsal joints are usually considerably widened, and clothed beneath with a brush of hair. In many the outer surfaces of the tibiæ are also a little hollowed, with long hairs growing from their margins, which renders them very serviceable in collecting and conveying to the nest the pollen of flowers. The surface of the body is in most Bees covered with hairs.

The general appearance of Bees is pretty well known. They are generally rather stoutly-built insects, at all events for Hymenoptera, having a head of moderate or considerable size, antennæ of moderate length, an ovate thorax, and usually an ovate abdomen, although this last part is subject to considerable variation in point of shape. Their food in the perfect state consists almost exclusively of the nectar of flowers, which, as already mentioned, they lick up with the hairy ligula which forms the central piece of the proboscis. The larvæ feed upon nectar mixed with the pollen of flowers, and in all cases live in a cell, which is stored, or supplied at intervals during the growth of the larva, with the necessary stock of food. There is, however, great diversity in the mode of construction of these habitations, which are placed in very varied situations and composed of different materials.

Entomologists divide the family of the Bees into two great groups, the first of which is distinguished by having the tongue, or ligula, long and slender, and the labial palpi composed of two long and two short joints, the latter often stuck on at an angle close to the apex of the second long joint; while the second have a shorter and broader tongue, and labial palpi composed of four



HEAD OF BEE (*Anthophora*).

a, antenna; e, eye; md, mandible; lr, labrum; mx, maxilla; sup, maxillary palpus; lb, labium; pg, paraglossæ; lp, labial palpus.



Queen.

Worker.

Male.

THE HIVE BEE.

The HIVE BEE (*Apis mellifica*) would take a volume as large as the present for the due elaboration of its natural history, and such a volume might almost be written with less trouble than the short account that our space here compels us to give of it. We must, however, attempt to indicate in a few words the main outline of the natural history of an insect which, perhaps more than any other, has in all ages attracted the attention of mankind.

The ordinary Hive Bee, as is pretty well known, is a blackish-brown insect, clothed generally with greyish-brown hairs, with slight indications of paler bands on the abdomen. As a social species, it is, as already explained, represented by three adult forms, namely, males, perfect females,

nearly equal joints, similar to those of the maxillary palpi. The first group includes the most typical of Bees, and especially the genus *Apis*, to which the Hive Bee belongs; it may therefore be denominated the sub-family *Apidae*.

and workers, or undeveloped females. These three forms are found together in the hive in the summer months; at other seasons only the two forms of females. Of these the perfect females are usually more brightly-coloured than the workers; their general form is longer (the workers being half an inch and the females seven or eight lines long); the abdomen is long and tapering; the wings, when closed, do not reach the apex of the body. The eyes in both females and workers are of moderate size, and confined to the sides of the head. The males, or drones, are about as long as the females, but of a much stouter form of body; their wings are larger, and their eyes so large as to meet on the crown of the head. On the other hand, in the workers the basal joint of the posterior tarsi is concave, and marked across with ridges, each of which bears a fringe of bristles, making a sort of basket for carrying pollen. This apparatus is wanting in both the males and the perfect females.

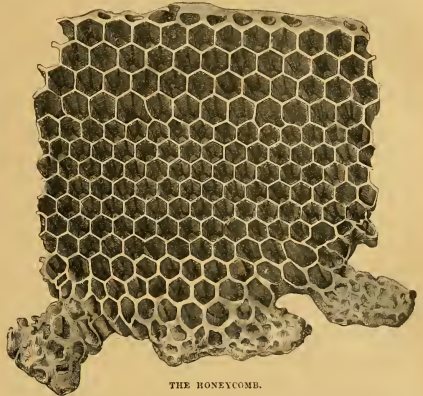
In Southern Europe, notably in Italy, a much more brightly-coloured Bee is found, distinguished especially by having yellow transverse bands on the abdomen. This Bee was long supposed to be a distinct species, and was described under the name of *Apis ligustica*, but it is now regarded as merely a variety, and, under the name of the Italian or Ligurian Bee, has of late been introduced into the more northern parts of Europe. Two other banded varieties (or species) are known in Africa, and another in China. As to the country in which the Hive Bee originated, nothing can be said. It appears to have been known since the earliest dawn of history, and is now in one or other of its forms spread over nearly the whole surface of the earth, and in some localities in warm climates is even found in a wild state, but whether truly wild or only escaped from captivity is a question.

In all cases, however, the habits of the insect are the same. The nest is built in the protection of some hollow in the wild state, usually in a hole of a tree; under domestication, in a hive of some sort. It would be futile to attempt any description of the immense variety of hives which have been invented to serve as the homes of Bees. The old straw hive, the appearance of which must be familiar to every one, has no doubt come down to us from a very remote antiquity, and was the only form known during the long period in which the cultivation of Bees was a matter of great importance. The introduction of a second hive, or "super," placed above the one in which the Bees live, so as to enable the produce of their industry to be removed without sacrificing the Bees, was a great step in advance; and the employment of wooden hives with glass sides, enabling the whole economy of the community to be easily superintended, has not only revealed to us most of the secrets of Bee-life, but at the same time placed the management of the hive completely in the hands of the owner. At the present day the Bee-keeper can actually govern the reproduction of his stock, by introducing into the hive the foundations of cells of the size proper for receiving male or female eggs.

During the winter and spring the community consists exclusively of female individuals, namely, a single perfect female or "queen," and a multitude of workers. The business of the former is to lay eggs; that of the latter to perform all the necessary operations for the maintenance of the hive and the support of the young.

The actual nest, if we may call it so, built by the workers within the hive, consists of a series of so-called "combs" suspended perpendicularly side by side within the cavity of the hive, and formed of numerous hexagonal cells laid horizontally, that is, at right angles to the general direction of the comb. Each comb consists of two sets of cells opening on its opposite sides, and therefore placed end to end and separated by a very thin plate of material; and it is remarkable that the cells are not placed directly end to end and terminated by flat surfaces, but so that each cell is closed by portions of three cells on the other side of the comb, an arrangement which, as will be seen, insures a certain economy of space. Thus, the cell, which is a hexagonal prism, is terminated by a small pyramid composed of three rhomboidal faces, and as these belong to three cells on the other side, the apex of the pyramid, forming the deepest part of the cell, is placed at the junction of three sides of the cells on the other side of the comb, so that the deepest parts of the cells on one side fit into the shallowest parts of those on the other. This marvellously ingenious arrangement has long excited the admiration of mankind, especially since it was found that in the form of their cells and in the shape and arrangement of the pieces closing them, the Bees approximated very closely to the proportions which, according to theory, were most advantageous. The accuracy of Bee architecture was, indeed, a little exaggerated, as such an example suited admirably a certain school of writers whose delight it was to undervalue all manifestations of the human intellect. Nowadays, this sort of

misplaced enthusiasm is fortunately going out of fashion, and we can admire what is admirable in the architecture of the hive and in the wonderful polity of its inmates, without ascribing almost miraculous powers to the latter. The Bee's cell is a hexagonal prism, because the insect endeavours to get as many cells of proper size as possible into the space at its command ; and the hexagonal prism is the form most nearly approaching a cylinder, any number of which of equal size may be placed side by side without leaving any vacant spaces between them. The cells may therefore be regarded as attempted cylinders which have become converted into six-sided prisms by what may be called mutual pressure. This is further evidenced by the fact that the cells close to the part where the comb is attached for suspension, and some of those at the junction of rows of different sizes (see figure), are more or less irregular in form ; and also that those which occupy the free edges of the comb follow the prismatic form only on the side turned towards the solid comb, the outer surface being irregular or rounded.



THE HONEYCOMB.

The same inherited instinct that prompts the Bees to build these elaborate double combs also teaches them that, in order to effect their object, namely, the production of the largest number of cradles for their young, in the smallest possible space and with the smallest expenditure of a valuable material, they must adopt the principle of making the cells alternate on the two sides of the comb, and their adoption of this plan furnishes the explanation of the whole phenomenon. The material used, as is well known, is wax, a peculiar substance secreted by the workers from between the segments of the abdomen. When this secretion is going on, the workers engaged in it cling together in numerous festoons, forming a mass that has been compared to a curtain, and the process may last for some four-and-twenty hours. When the secretion of the wax is completed, it projects from between the abdominal segments in the form of thin plates, which the Bees then proceed to detach and make use of in comb-building. It is taken in fragments into the mouth, where it undergoes a process of mastication, and is probably moistened with some fluid which renders it easier to work ; finally it issues from the mouth of the Bee in the form of a small white riband. The place for the formation of a comb having been selected, the wax-producing Bees build up a small plate of wax, usually of a nearly semicircular form, upon the



UNDER SURFACE OF BEE, SHOWING THE WAX BETWEEN THE SEGMENTS.

line corresponding to the partition of the future comb, and this at first has no indication of cells. But when the first small plate has been got together the Bees go to work upon it and dig out small hollows in its substance, which they afterwards enlarge, working simultaneously on both sides, and reducing as much as possible the thickness of the partition between them. As the Bees do not work directly opposite to one another, the deepest part of the hollows on one side will correspond with

partitions between the hollows on the other. As the hollows are approximately equidistant and of the same size, each hollow is opposed to parts of three on the other side of the plate; and as the Bees are constantly working on both sides for the purpose of thinning the partition wall, a time would speedily come when each curvilinear hollow would be broken through in three places unless they ceased or modified their operations. This is precisely what they do. They avoid piercing the partition, but by subsequent action upon both sides of it produce exactly the same effect that would be produced by the mutual pressure of the same number of plastic bodies with a similar curvature, namely, the formation of flat limiting planes, of which each cell has three. As the same operations are going on all round, the original circular form of the hollow becomes converted into a hexagon, and thus the three terminating plates acquire the rhomboidal form that we see. In this way the foundation of the comb is laid, and the plan of the hexagonal cells which are afterwards built is marked out.

Of the formation of the cells we need say but little. The plan being sketched, or rather, perhaps, as the plan is being sketched (for it must be remembered that operations which we have to describe in succession may be simultaneously carried on by a crowd of little artificers like the Bees of a hive), the Bees begin to raise the edges of the hollows representing the bottoms of the cells, and these are built up to the required height by additions of wax moulded and worked by the Bees to the requisite degree of thinness. The building progresses rapidly downwards. New cells are commenced long before the earlier ones are finished, so that the increasing comb is thickest at its point of attachment, and becomes thinner towards the edges, and especially towards the bottom. In fact, it is not until the comb is completed that it acquires those nearly parallel surfaces which we are accustomed to see in ordinary honeycombs. When the first comb has advanced a little, the Bees lay the foundation of other combs parallel to and on each side of it, and at the proper distance apart; and as the cells are completed, they finish them off by applying round the edges and along the lines of junction of all the waxen plates composing them a thin coating of the resinous substance called *propolis*, which they collect from the opening buds of poplars and other trees, and employ for a variety of purposes in the economy of the hive, especially for stopping crevices, fixing loose parts, and covering up noxious objects which are too heavy for them to remove.

The cells in the combs are of different sizes, according to the use to which they are to be put. Those for the rearing of worker-larvæ are the smallest, and worker-combs are about an inch in thickness. Drone-cells are of larger diameter, and rather longer than those of workers; hence drone-comb is thicker than worker-comb, and when patches of drone-cells occur in the midst of worker-cells the comb becomes deformed and irregular. Besides these two kinds of comb-forming cells, there is a third of the same general shape and construction, specially designed for the storing of honey. The cells forming store-combs are generally as wide as drone-cells, but much longer—sometimes as much as an inch and a half in length. The passages left between the parallel combs are about half an inch wide.

As the brood-cells are completed by the labours of the workers, the queen proceeds to deposit her eggs in them. She first inserts her head into the cell, as if to see that it is properly prepared for the reception of its new tenant; then, withdrawing her head, she bends her body down into the cell, turns half round, and deposits an egg at the bottom of the cell. This process is repeated at each cell, and it is remarked by bee-masters that the queen usually deposits her eggs equally on both sides of the comb, which may no doubt assist in economising the warmth of the brood. In a populous hive there may be from 40,000 to 50,000 workers, incessantly engaged in the various operations of the hive, of which the preparation of cells for the reception of the eggs is one of the most important, as may be supposed when it is estimated that a vigorous queen will lay from 2,000 to 3,000 eggs daily in the height of summer, or, as Dzierzon calculates, 60,000 a month, and during her average life of four years over a million eggs. This extreme fertility is the more surprising as the eggs produced are of comparatively large size—nearly one-twelfth of an inch long. It is to be observed, however, that the queen, when laying, is always accompanied by an obsequious crowd of her subjects, not only ready, but urgent, to furnish her with an abundance of food, so that she may be compared to a machine receiving food as a raw material, and incessantly converting it into eggs, and turning out the finished articles at the rate of about 100 per hour.

The egg, which is of an elongated form, and slightly curved, is deposited on the bottom of the cell by one of its ends. The cell is then furnished by the workers with a small mass of a peculiar jelly elaborated by the workers from a mixture of honey and pollen, and disgorged by them into the cells. On the fourth day the larva is hatched, and, having consumed the food placed ready for it, stretches itself towards the mouth of the cell, and is then abundantly supplied with food by the workers. Under these favourable circumstances it grows very rapidly, and in six or seven days attains its full size, and fills up the whole cell. The workers then cover the cell with a sort of lid, composed of wax mixed with pollen; and thus protected the larva soon spins a silken cocoon, within which it casts its skin for the first time, and becomes a pupa, with the wings and limbs enclosed in separate cases. On the twenty-first day the perfect insect emerges, and after a delay of a few hours, during which the various parts of its body dry and harden, it at once begins to take part in the various labours of the hive, but does not venture out for a week or a fortnight. As soon as the insect has emerged from its cell, the latter is cleaned out and prepared for the reception of a new inmate; but as the cocoons are left behind, and a certain amount of dirt clings to the used cells, these gradually become dark in colour and reduced in size by the accumulation of cocoons, an effect speedily made perceptible by the smaller size of the workers produced from the old combs. The workers, which generally live only about six weeks in the height of the season, continue to be produced, when the weather is favourable, until October. The business of these workers, besides the building of the cells and care of the young, as already indicated, consists chiefly in the bringing in of supplies of honey and pollen, both for immediate consumption and to be stored against the flowerless season of the year. In pursuit of these substances, the worker-bees are incessantly on the wing during fine weather, passing busily from flower to flower, and when loaded flying straight home to their own hive, to which they are directed by an instinct of locality which is perfectly marvellous. At the end of the year, and during the winter, parts of the combs are entirely filled with honey, which is also found occupying the upper rows of cells in most of the combs, while the remainder are either empty, waiting for the next season's brood, or filled with pollen, or "Bee-bread," as it is called, carefully laid up, and, like the honey, shut into the cells by little waxen lids. The pollen is carried home chiefly upon the dilated hind legs, the honey in the sucking-stomach, from which it is disgorged either for the supply of the larvæ or into the store-cells.

During the winter the Bees remain congregated in the hive, where they keep up their heat by close packing and a certain amount of exercise. The temperature of the hive rarely falls below 45° Fahr. Activity usually recommences in April, and the first business is a general "house-cleaning," including the removal of the bodies of those Bees which have died during the winter, the repair of any damage that may have happened to the combs, and the clearing out of the numerous wax-lids, detached from the cells of which the honey has been consumed, which lie about as they fell upon the floor of the hive. These necessary operations having been performed, the Bees, if the hive has not suffered much during the winter, set about the preparations for a new phase in their existence, namely, the emigration of a portion of the population to found a new hive. Drone cells are prepared, and in each of them the queen lays an egg. The workers furnish the larvæ with the necessary food. They become full grown on the eighth day of their existence, and the cells containing them are then closed up with a lid in the same way as those of the worker-bees. On the twenty-fourth day after the laying of the egg the lids open, and the drones or males come forth.

As the drones begin to make their appearance another form of cell is produced, generally on the margins of the combs. Here the workers make a more or less irregular chamber, usually with its mouth turned downwards, in which, instead of endeavouring to be sparing of material, they seem recklessly to employ a quite unnecessary quantity. In this cell the queen also lays an egg,* and the larva, when hatched, is fed by the workers throughout its life in that state with the peculiar jelly-like

* This is the general impression: but some bee-masters, and among them Mr. John Hunter, whose "Manual of Bee-keeping" is one of the most intelligent books on the subject, is of opinion that the queen does not lay in the royal cells, but that the workers, when they consider it necessary to produce new queens, take eggs already laid in worker cells, or even young worker larvæ, and enclosing them in royal cells, feed them with royal jelly, and thus produce the young queens. That a new queen can be produced in this way should the hive be accidentally deprived of its sovereign is a perfectly well-known fact.

food which constitutes the first meal only of the worker larva. The consequence of this difference of treatment is that the larva attains its maturity in six days, when it is closed up in the usual manner, becomes transformed into a pupa, and in sixteen days gives birth to a fertile female or queen. As the queen-bees are so jealous that two of them cannot live together in the same hive, the old queen, when she becomes aware of the presence within her realm of a possible successor, becomes much agitated, and would doubtless destroy the young female, whose existence is betrayed by a sharp piping sound, if the workers did not carefully keep the latter in her cell. In course of time the agitation of the old queen becomes extreme, and communicates itself to the other Bees in the hive, which grow exceedingly disquieted, display great activity, and in consequence raise the temperature of the hive to an almost unbearable pitch. This is generally revealed by a tendency on the part of the Bees to issue from the hive in great numbers, and by clinging together suspend themselves in a compact mass just outside the entrance to the hive. This process is called "clustering," and is generally to be taken as an indication that "swarming" is about to take place. Sooner or later, at any rate, a great swarm of Bees, frequently numbering ten or fifteen thousand in strong hives, will rush out of the hive, carrying with them the old queen. They spread in every direction through the air, often to such an extent as to have been compared to the flakes of a heavy fall of snow. In a few minutes, however, the queen, who, from being heavy with eggs, cannot fly far, and some of the Bees, settle upon the branch of a tree or some other projecting object; others collect upon these, until at last a large ball of Bees is formed, having their queen in their midst. This is taken into a new hive, and constitutes the foundation of a new colony.

The young queen's first thought on escaping from the cell in which she was reared is to proceed at once to destroy any sisters that she may happen to have, and in this seemingly unnatural course she is abetted, and even aided, by the workers, unless their instincts tell them that further swarming will be immediately necessary for the well-being of the hive. In the latter case they prevent their new sovereign from carrying out her murderous intentions, and, according to some writers, will, with this object in view, treat her very unceremoniously.

From two days to a week after her emergence the young queen takes her nuptial flight, for in the Bees, as in many other insects, the union of the sexes always takes place in the air. Whatever may be its object there is no doubt that this is what occurs in the Bees, and there is ample evidence that the nuptials of these insects are celebrated during flight. In quitting the hive the young queen is described as taking a careful survey of it and its surroundings, apparently so as to identify it on her return. She then starts off and is soon out of sight. A day or two after she has returned to the hive she usually commences her regular maternal duties, which she continues to perform without ever quitting the hive, until she goes forth as the leader of a swarm.

According to some experienced Bee-keepers the drones of the hive do not take to flight with the young queen, but the nuptial flight is undertaken with the purpose of meeting drones from other hives, and thus securing the benefits of cross-fertilisation. Later princesses produced in the hive go off as the leaders of after-swarms, and these we might certainly expect to be impregnated by drones from other stocks. But, on the other hand, we have the remarkable fact that as soon as all the fertilisable females have emerged from their cells or been destroyed, the surviving drones, as though considered no longer of any use, are ruthlessly massacred by the workers, and thrown out of the hive.

It has already been mentioned that in the Bee, and probably in other social Hymenoptera, workers occasionally occur which possess a certain limited fertility. These workers in the case of the Bee always produce drone-eggs; and in fact it was the recognition of this fact that led originally to the establishment by Von Siebold of the theory of the constitution of the Bee community, which is now generally accepted. These partially fertile workers, which become a nuisance in the hive, have part of the ovaries sufficiently developed to produce eggs, but, as they are incapable of impregnation, these eggs cannot be fertilised, and hence produce only drones. Why the partial development of the ovarian organs takes place is not known with certainty, but it may be inferred with considerable probability that the larvae of these workers were brought up in cells near the royal cells, and that some portions of the food intended to bring the young queens to maturity fell to their share.

That we have devoted so much space to the natural history of the Honey Bee is due to the fact

that it furnishes an example of the most perfect society that we shall have to notice, and hence the explanations here given will serve to render intelligible the much shorter accounts that we must give of the other social types. But the preceding description is necessarily very imperfect, and hundreds of interesting points have been left altogether untouched. Of the economical importance of the Bee, and of the methods of its cultivation and treatment in various countries, we have been perforce silent. The principal enemies of our Bees are the larva of the Honeycomb Moth (*Achroia albearia*), that of a small beetle (*Trichodes apiarius*), and the great Death's Head Moth (*Acherontia atropos*). A small insect known as the Bee Louse (*Brachia lea*), which belongs to the order Diptera, although it has no wings, lives as a parasite upon the Honey Bee.

Nearly related to the Hive Bee are numerous wild Bees inhabiting various parts of South America, and forming the genera *Melipona* and *Trigona*, those of the latter generally of very small size. Like the Hive Bee these are social in their habits, build their cells with wax (which, however, is said to escape between the dorsal instead of the ventral scales of the abdomen), and store up honey. They generally live in hollow trunks of trees, but also in holes and fissures in the ground, and line their residences with clay and resinous materials. In the use of their wax for the formation of the brood-cells and store-places they are by no means so economical as the Hive Bee. The former are in a single row in each comb, thick-walled, and with rounded bottoms; the combs are placed horizontally, and the upper ones supported by waxen pillars, and the openings of the cells are turned upwards; the store-cells are of large size, irregularly ovate, and massive. These insects possess no stings, but bite severely.

The HUMBLE BEES (*Bombus*), of which we have some eighteen British species, are too well known as to their general appearance to need any description. Large, heavy insects, flying buzzing along in the summer air, they present a considerable contrast to the much lighter Hive Bee, and in their habits also a similar contrast prevails. The genus is very widely represented, species of it occurring in Europe, Asia, and America; and, although it appears to belong properly to the northern regions, several species are found in South America. None, however, are known to occur in Australia, New Zealand, or Africa. The individuals vary greatly, especially the males, which renders the determination of the species often a matter of considerable difficulty.

Like the Hive Bee, the Humble Bees are social, but their societies are not permanent. In fact, they are rather families than societies, for each community springs in the course of a single season from a female which has survived from the previous year. These females are to be found hibernating in moss at the roots of trees, in the hollows of decayed trunks, under stacks, and in other dry and sheltered situations. With the first genial weather of spring each of these sets to work to prepare a nest and found a new colony. The nests are built either in or on the ground—in the former case the foundress Bee often takes advantage of some burrow or other ready-made cavity; in the latter the nest is usually composed of moss, although other materials, such as dried grass and leaves, are often employed. The nest first made is a very small affair, intended to serve only for rearing a few workers to take part in their mother's labours. The female makes no cells for the reception of her progeny, but brings into the nest a quantity of pollen and honey, which she places in a heap, and then lays some eggs in it. The larvæ from these, when hatched, feed freely on the store of food provided for them, and on the further supplies brought in during their growth by their mother. Like the larvæ of the Hive Bee they grow very quickly, and in a few days become full grown, and prepare for their change to the pupa state by spinning a silken cocoon, which is so delicate as to be almost transparent. In this they pass their period of repose, and, in emerging from the cocoons, gnaw through one end of them. The empty cocoons, placed side by side with these openings upwards, resemble so many little pots, and serve afterwards as vessels to store supplies of food. Later on, besides more workers, some small females, which are supposed to lay only drone-eggs, make their appearance, and, about the same time or later, drones are produced. Then towards autumn large females, similar to the original foundress of the colony, show themselves in the nest, and these, after impregnation, conceal themselves in sheltered places to pass the winter as already described.

Several species of Humble Bees are very common in Great Britain, and most of these are widely distributed on the continent of Europe. One of the best known is the *Bombus terrestris*, the large

females of which may attain a length of nearly an inch. It is thickly covered with black pubescence, but with the front of the thorax, a band across the middle of the abdomen, and its extremity yellow. In another rather smaller species (*Bombus lucorum*) the colours are the same in the female and worker, except that the extremity of the abdomen is white; but the male is clothed with yellowish pubescence, except the apical portion of the abdomen, which is white, and some more or less distinct black bands on the thorax and abdomen. Both these species are subterranean Bees. Of the moss-builders, the best known perhaps is the *Bombus muscorum*, the largest specimens of which are about two-thirds of an inch long. This is clothed with dull yellow pubescence, which becomes tawny on the thorax, and shows more or less distinct traces of black bands on the abdomen. *Bombus lapidarius*, so called from a preference it shows for making its nest under stones, is the well-known large black Humble Bee, with the end of the abdomen orange red. The male has the face, the front of the thorax, and the scutellum yellow.

The numbers of individuals in the nests of the Humble Bees are very small when compared with the multitudes which swarm in a bee-hive. According to the late Mr. Frederick Smith, those of *Bombus terrestris* contain the largest number known to him, and he records that a nest of this species

taken in August contained only thirty-five females, twenty males, and one hundred and sixty workers; whilst in a nest of *B. fragrans* at the same season only five females and about twenty workers were found.

These true Humble Bees, which are among the most industrious of insects, passing their lives in incessant activity, and bringing in large supplies of pollen and honey to their nests, are provided, like the Honey Bee, with greatly-dilated hind tibiae and tarsi, thickly fringed with long bristle-like hairs, which render them efficient instruments for the conveyance of pollen. There are, however, certain nearly-allied Bees resembling them in general characters, and even in the dilatation of the hind tibia and



APATHUS VENTILIS.

first tarsal joints, but in which these dilated parts are destitute of the hairs and bristles which render them so useful as pollen-baskets, so that at the first glance one would conclude that they cannot follow the same mode of life as the true *Bombi*. In point of fact, these Bees, which have been formed into a distinct genus under the name of *Apathus*, are parasitic upon the true Humble Bees, visiting their nests, depositing their eggs there, and leaving the care of rearing the larvæ to their industrious relatives. Four British species are recorded, the most abundant of which are

Apathus barbutellus, a black species about three-quarters of an inch long, which has the front of the thorax and the scutellum tawny, and the apex of the abdomen white; and *A. vestalis* (see figure, p. 366), which is rather larger and also black, with the front of the thorax orange-yellow, and the end of the abdomen white, with a blackish or brownish spot at the apex. Of these insects there are only perfect males and females. From their habits no workers are necessary.

In the Humble Bees we have the conditions of social Bee-life reduced to their simplest form. There are workers, it is true; but the females also labour. The nest is really a family dwelling. No cells are formed, and the larvæ feed upon a mass of pollen and honey brought into the nest. In the Solitary Bees, which form the remainder of the family, we have, in a slightly modified form, the same series of phenomena that are involved in the first foundation of the Humble Bee colony. The female Bee makes her nest, stores it with food, and deposits her egg upon the latter; but she lays in a sufficient store for the support of the larva until it attains its full growth, and then closes up the nest, and leaves it to itself. The larva, having consumed the provision laid up for it, spins a cocoon, and undergoes its change to the pupa state, in which it usually remains until nearly a year has elapsed from the time of the egg being laid, and then the perfect Bee makes its way out to seek its mate and provide for the continuance of its species.

In their habits, these Solitary Bees show considerable diversity. A great number bore holes in decayed wood, such as old posts and trunks of trees; others select the stems of such plants as brambles and briars, from which they bore out the pith, making a tubular nest which they occupy with their cells. Some of these, again, save themselves the trouble of hollowing out a nesting-place by the simple process of making use of the ready-prepared tubular cavities offered to them by the straws of thatch, cut reeds, and similar articles. A great number burrow in the ground, some selecting sandy, others clayey situations, but generally in the face of a sloping bank or cliff; and others, again, pierce the mortar of old walls, and there form the cells for their young. These cells are not composed of wax, but either of earthy or vegetable materials, and we need not say that they never possess the beautiful hexagonal form characteristic of those of the Hive Bee.

Of the Scopulipede Solitary Apidæ, or those furnished, like the Hive Bee and the Humble Bee, with an apparatus for the conveyance of pollen on the hind legs, we may notice, in the first place, a very common spring Bee, the *Anthophora acervorum*, the female of which resembles a rather small black Humble Bee, with the hairs on the hind legs reddish-tawny, whilst the male is clothed with tawny hairs, and has the intermediate legs much elongated, slender, and adorned with curious fringes of black hairs. This Bee swarms in the neighbourhood of banks and cliffs as early in the year as April. Its burrows are made in such situations, and occasionally in the mortar of old walls, barns, &c.

The VIOLET CARPENTER BEE (*Xylocopa violacea*), which belongs to a genus best represented in warm countries, inhabits the south of Europe, but extends northwards into Germany. It is a large insect much resembling a Humble Bee, of a black colour, with violet wings, upon which it flies noisily in the sunshine, seeking a suitable place for its nest, for which it usually selects a wooden post or the dead trunk of a tree. Having chosen a favourable position, the female sets to work with her powerful jaws, and speedily gnaws straight into the wood for a short distance, and then, turning downwards, proceeds to excavate a large tunnel in the interior of the post or tree, sometimes for a distance of a foot or more. This laborious work being completed, the industrious insect collects a quantity of honey and pollen, which she deposits in the bottom of the nest. Upon this she then lays an egg, and covers up the whole with a roof composed of concentric rings of the fine dust produced during her boring operations carefully kneaded together. This serves at once as a ceiling for the first cell and a floor for the second. Upon it a fresh supply of food is deposited, with another egg, followed by a second transverse partition, and the same processes are repeated until the whole tubular dwelling is occupied. There is some reason to think that in the warmer countries inhabited by it there are two broods of this Bee in the course of the summer. The *Xylocopæ*, although so scantily represented in Europe, have over 100 species in the tropical parts of the earth. The nearly allied genus (*Euglossa*), found in South America, is remarkable for the great development of the tongue, which is two-thirds the length of the body. One fine species, over an inch long (*Euglossa dimidiata*), found in Brazil and Surinam, is velvet-black, with a metallic-green abdomen, having three transverse bands of yellow hairs, and the extremity clothed with bright red hairs.

Closing our account of the Scopulipede Bees with this brilliant foreigner, we must now proceed to notice a few types of another group, to which the name of *Dasygastres* has been given, in allusion to their having the lower surface of the abdomen densely clothed with hairs, upon which they collect and convey home the pollen for the supply of their young. These Bees, represented in Britain chiefly by the genera *Osmia* and *Megachile*, present a most interesting variety of habits, and, in fact, examples of all the peculiarities already mentioned, modified in various ways, may be observed among them. Of the first of these genera, Mr. Frederick Smith, in his "Catalogue of British Bees," says :—"If I were asked which genus of Bees would afford the most abundant materials for an essay on the diversity of instinct, I should without hesitation point out the genus *Osmia*." A species described by Réaumur



OSMIA LEUCOMELANA AND ITS NEST.

under the name of the MASON BEE (*Chalcidoma muraria*), nearly allied to *Osmia*, builds its nest, composed of fine sand-grains very firmly united by a salivary secretion, upon the surface of walls, selecting, in the first place, some small cavity or hollow which may help to give a firm foundation. Here the insect builds a cell somewhat resembling a small finger-stall, with the opening upwards, smooth on the inside, rough outwardly. When nearly completed this cell is furnished with a supply of food, and an egg is laid in it; then

the top is closed, and the industrious mother sets to work to build another cell, and this process is repeated until circumstances induce the female to seek another place. The cells are placed without any particular order, and Dr. Taschenberg says he has never seen more than ten together. This Mason Bee has not hitherto been found in Britain.

The most abundant British *Osmia* is the Horned Bee (*Osmia bicornis*), of which the female is remarkable for having two little horns projecting from the front of her head. This species usually burrows in sandy banks and cliffs, but when living in clayey districts chooses decaying trees, especially willows, for its nests. Another species (*Osmia leucomelana*) selects for its breeding-places the dead branches of the common bramble, the pith of which it scoops out to a depth of several inches, and then deposits its eggs, with a supply of food, in a series of cells separated by partitions formed of masticated vegetable matter. This Bee shows great ingenuity, for it does not remove the whole of the pith, but leaves portions projecting in the form of rings, which help to make the partitions between the cells. *Osmia hirta* and some other species burrow into wood; whilst two British species (*O. aurulenta* and *bicolor*) select ready-made nests in the shells of the common snails (*Helix hortensis* and *H. nemoralis*), within the whorls of which they build their cells of gnawed vegetable materials.

The nearly-allied Bees of the genus *Megachile* are commonly known as Leaf-cutters, from the habit they have of cutting portions of the leaves of trees and plants for the purpose of lining their nests. The pieces of leaf are cut by the mandibles with the utmost neatness, and when detached are carefully rolled up, tucked between the legs, and flown away with to the nest. The rose, laburnum, and garden acacia seem to be the favourite trees with these insects, which form their nests in



LEAF-CUTTING BEES AND NESTS.

burrows, either in the ground or in decaying trees, and line them neatly with the portions of leaves so arranged as to separate the different cells, which roughly resemble so many thimbles placed one within the other. The commonest British species (*Megachile centuncularis*) is very widely distributed, being spread apparently over nearly the whole northern part of the globe. An allied species, the Poppy Bee, the Upholsterer Bee of Réaumur (*Anthocopa papaveris*), is remarkable for choosing the petals of the common poppy as the material for lining her nest.

As in the case of the Humble Bees, there is a contrast to this picture of industry. Several genera of true Apids do not take the trouble of preparing or storing any cells for their young, but foist their progeny upon their more industrious relatives. These Cuckoo Bees, as they have appropriately been

called, may be distinguished by their want of any apparatus for collecting pollen, either in the form of dilated hind legs furnished with bristles, or in that of a thick coat of hairs on the lower surface of the abdomen. The best-known of these parasites are the species of the genus *Nomada*—slender, smooth, shiny insects, more like Wasps than Bees, and generally adorned with bands of yellow and black, or red. These gaily-coloured insects may be observed flying about the sunny banks in which other Bees delight to form their nests. They make their way into the nests, in the absence of the rightful owners, and deposit their own eggs upon the masses of food stored up for the intended occupant. It seems probable that the nest-making Bee, finding



MASON BEE.

A, Male in flight; B, Female working at Nest; C, Female in front; D, Completed Nest.

on her return that an egg has been laid, takes it for granted that it is one she has deposited, and forgotten, and so closes up the cell; but Mr. F. Smith was of opinion that the *Nomadae* themselves might perform the latter operation, as he had occasionally observed these parasitic Bees with small masses of clay attached to their hind legs.

The second principal group, or sub-family, of Bees, called *Andrenidæ*, from the name of the principal genus, includes no social species. As already stated, the tongue in these Bees is short and broad, and the labial palpi consist of four nearly equal joints, like those of the maxillary palpi.

The true *Andrenæ*, of which a large number of species inhabit Great Britain, are all burrowers in the ground, sometimes in banks of light sandy earth, sometimes in firm soil, and even in hard-trodden pathways. Their burrows run to a depth of several inches, and terminate usually in a single oval cell, but occasionally the Bee makes branching tunnels, so that a single entrance passage

may serve to give access to several cells. In the nearly allied genus *Halictus* (or *Hyleus*) this habit of multiplying the cells seems to be general. In all, the cells terminate the tunnels, and when stored with food and furnished with eggs the female closes the aperture of the burrow. As a general rule the development of these burrowing Andrenidæ takes place in the following fashion:—The larva, when hatched, feeds upon the supply of food left for it, undergoes its change to the pupa state, and in this condition remains in its cell through the winter, to emerge at the same season of the year at which the egg was laid; but in some cases there appear to be two broods in the course of the year; and in *Halictus* and an allied genus (*Sphecodes*) it would seem that the insects escape from the nests in the autumn, and the females, after impregnation, survive the winter in sheltered places, and commence their nest-making operations in the spring, thus following the same course as the Humble Bees. The species of *Sphecodes* are very unlike Bees in their general appearance, being generally smooth black insects, with more or less of the abdomen red, and the females have no apparatus for carrying pollen either on the legs or the abdomen. Other species of this group, especially those of the genus *Prosopis*, have been observed to make their nests in bramble-sticks.

The Andrenidæ are particularly subject to the attacks of those peculiar parasites which infest Bees, especially the coleopterous Stylopidæ and Meloidæ.

FAMILY VESPIDÆ, OR WASPS.

The Wasps, which, like the Bees, are both social and solitary in their mode of life, form the second family of the aculeate Hymenoptera, called Vespide, from the name of the genus (*Vespa*), which includes the best known species. One of their most striking characters is to be found in the fact that the fore wings, which, as in the Bees, have either two or three submarginal (or cubital) cells, are capable of being folded down the middle, so that the wings of each side of the body form a straight band only about half the width of the fore wing. The first discoidal cell is very long, being much produced towards the base of the wing. In their general structure they approach the Bees, but are of a more slender form, and usually much less hairy. The posterior tibiæ and tarsi are simple and not dilated; the sides of the prothorax are produced back as far as the root of the wings; the antennæ are, as in the Bees, more or less knee'd at the end of the long first joint; the eyes are kidney-shaped; the mandibles well developed and prominent; and the maxillæ and labium do not, as in the Bees, form a sort of proboscis. The labium is wide in front, and its palpi are either three or four-jointed; the maxillary palpi consist of six joints. Species of this family occur in nearly all parts of the world, and about 1,000 of them are known.

The social forms, which, in the beauty of their architecture rival, if they do not excel, the Hive Bee, are distinguishable from the solitary ones by certain structural peculiarities; the claws at the ends of the tarsi are simple, and the mandibles are broad. These insects live in communities of various sizes according to the species, consisting, as in the Bees, of three kinds of individuals, males, perfect females, and workers. Their nests, which are among the most beautiful examples of insect architecture, are found either in holes in the ground, or in hollow trees, and similarly sheltered situations, or freely suspended from the twigs or branches of trees. The material of which they are composed is a sort of rough paper or cardboard, composed of portions of plants, usually woody in their nature, gnawed up by the insects and brought into the condition of a paste by means of their salivary secretion, which is of so viscid a nature as to hold the particles of vegetable matter very solidly together. In fact, the material of which the nests and cells are constructed often shows a marvellous smoothness of surface; the workmanship of the cells is always of great beauty. The cells are hexagonal in form and placed side by side so as to form regular combs, but there is only a single row of cells in each comb, and in most cases their apertures are turned downwards. The combs as they increase in number are placed one above the other, and usually attached to each other by small columns of the paper-like material of which the nest is composed.

Although some of the nests may contain several thousand individuals, and a much larger number of cells, each community (at any rate in temperate climates) originates from a single female Wasp, which, having arrived at maturity and been impregnated in the preceding autumn, and passed the winter in a state of torpor concealed in moss, or some other shelter, comes forth with the first mild days of spring and lays the foundation of the nest. The proceedings of this foundress of the colony are so

well described by the late Mr. Frederick Smith, that we cannot do better than quote his account of them. It relates apparently to the Common Wasp (*Vespa vulgaris*), and is as follows:—"Having found some hole in a situation adapted to her purpose, she proceeds to enlarge it and to form a subterranean chamber of suitable dimensions. Her next operation is to collect materials wherewith to lay the foundation of the nest itself. This is constructed of the raspings or scrapings of different kinds of wood. Having produced a supply, she first constructs a footstalk sufficiently strong to support the first two or three layers of cells. At the end of the column or footstalk she forms three cup-shaped receptacles; these are of course reversed, hanging bellwise; the depth of each is about the tenth of an inch. The Wasp now constructs a covering over the foundation-cells like an umbrella. An egg is deposited in each cup, and she then proceeds to construct additional ones, depositing an egg in each as soon as completed. By this time the eggs first deposited are hatched, and the larvæ now require a portion of her attention. The larvæ of Wasps grow rapidly, and, with the growth of the grubs, she from time to time raises the walls of the cells. The cells in the foundation-comb are never carried up higher than the length of the larvæ. As it increases day by day, the Wasp adds a fresh course of wall until the larvæ is full grown, when it covers itself in by spinning a convex cap to the cell of a tough, white, silky texture. The angles of the planes of the hexagons are determined by the points of contact of the circular bases. From these the Wasp gradually commences the flattened sides of the hexagons, at first a little curved, but at a slight elevation the sides become perfectly flattened planes, and as such are carried up to the required height."

The food of the larvæ, as of the perfect Wasps, consists in part of honey, which the latter obtain either directly from flowers or by plundering the Bees, in part of portions of succulent fruits, and in part of animal matters, and as soon as her first eggs are hatched the parent Wasp furnishes the larvæ with the necessary supplies of food. When their development is completed the young Wasps pass but a short time in the pupa state, and then emerge in the form of workers, which at once assist the female in the labours of the nest. Fresh combs are added beneath the foundation comb; the protective covering is enlarged and carried down in proportion as the building of the cells progresses, until at last, in the case of the Common Wasp and many other species, the nest forms a large ovate body, with a surface of rough paper, having a single opening for the ingress and egress of the inhabitants at the bottom. Within this the great business of reproduction goes on rapidly; workers are produced in great numbers; then females make their appearance, and finally males—the last only at the approach of autumn. After these and the young females have quitted the nest for their nuptial flight, the remaining inhabitants of the nest seem to have some consciousness that the end of their own lives is approaching, and that they will be unable to rear the young brood still in the combs. By a singular instinct, they proceed to pull the grubs out of the cells, carry them outside of the nest, and, after conveying them some distance from its entrance, drop them on the ground to die.

The general habits of the Social Wasps are pretty uniform except in the matter of their architecture, and in this respect they display a remarkable variety. Besides the Common Wasp (*Vespa vulgaris*), two other species found in Britain which build in the ground follow the same principles in the construction of their nests; but the Hornet (*Vespa crabro*), which is remarkable among European Wasps for its large size, builds its nest usually in the hollow of a tree, and the material of which it is composed is derived from the bark of trees, and often betrays its diversity of origin by the different colours of the successive portions added to the structure. Both the Hornet and the Common Wasp frequently build their nests under the eaves of houses, or attached to a beam under the roof, and in these cases the outer covering of the nest is thinner and more delicate in texture than when the dwelling is exposed to the vicissitudes of the weather. Some species of the genus *Vespa* make nests without any covering, and this is the general case with those of another genus (*Polistes*), the numerous species of which are spread over all parts of the world. The nests of these insects consist of combs of various sizes attached by means of short columns to the twigs and smaller branches of trees and shrubs, and freely exposed to the air. One well-known species is the *Polistes gallica*, which is common in France and Germany and throughout the south of Europe. Upon this species Prof. Siebold made some interesting observations confirmatory of his theory that the males of the Social Hymenoptera are produced from the unfertilised eggs of workers or females. Other species, of which the best-known inhabiting Britain is the Wood Wasp (*Vespa sylvestris*), build more or less oval nests, which they

suspend from the branches of trees. These nests have a comparatively smooth outer covering, with an aperture at the bottom, through which the Wasps pass in and out. The species of *Polybia*, and nearly allied genera, which are numerous in South America, produce a great variety of nests. Thus one species (*P. sedula*) suspends its nest by two or three short stalks from the twig of a tree, and as comb after comb is added the outer walls are carried down to unite and suspend the lower ones, so that the nest consists of a series of storeys, access to each of which is obtained by a small aperture in the outer wall leading into the space between two combs. Another (*P. rejecta*) builds its nest on the same general principles as the last, but leaves no apertures in the side walls. Instead of these access is obtained to the upper combs through vacant spaces left in the centre of all except the first. Some species of *Polybia* build their nests of earthy materials. The large size of many of these nests demonstrates the great number of individuals that live together in them. A nest of *Polybia liliacea* in the Paris Museum measures about five feet in length. *Tatua morio*, a common species in Cayenne, builds its nest on much the same principle as *Polybia rejecta*, but the apertures for access to the successive combs are placed on one side near the wall of the nest. Other species of the genus *Polybia* build nests agreeing in general construction with those of our indigenous Wasps when attached to trees; others, again, build their successive combs upon a twig or slender branch, which, passing through them, serves the purpose of a series of uniting columns; whilst one species (*Chartergus apicalis*) places each of its combs at the end of a short column springing nearly at a right angle from the supporting branch. All these nests have a protective covering.



POLISTES GALICA AND NEST.

Although we have only been able to refer in general terms to a few of the almost endless variety of beautiful structures made by the social forms, we must pass on to the Solitary Wasps (Eumenides), in which only true males and true females occur, and which are distinguished from the preceding by their deeply-toothed or bifid tarsal claws, and their generally long and slender mandibles. These are usually considerably smaller than our ordinary Wasps, but are nevertheless unmistakably wasp-like in aspect. They are generally black, with the thorax more or less spotted and the

abdomen ringed with yellow. The species are tolerably numerous and widely distributed. They breed chiefly in holes, which the female makes in various situations, sandy banks, dead and decaying wood, and old walls being preferred; but some of them construct small nests of earthy materials in which to deposit their eggs. The nests are generally furnished with a supply of insects or their larvæ, which the little freebooters ruthlessly seize and carry off for the sustenance of their offspring.

One of the commonest and best known species is the Wall Wasp (*Odynerus parietum*), which may be almost constantly seen haunting sunny walls during the months of June and July. It makes its burrows in walls and clay banks, digging out with its mandibles a small hole which may be three or four inches deep, and employing part of the materials removed in building outside the hole a tubular passage leading to it, which at first projects straight from the wall, but towards the end bends downwards. The object of this outwork may no doubt be to prevent the ingress of certain parasites, especially the Gold Wasps (*Chrysididæ*), which are incessantly prowling about with the object of introducing their eggs into the nests of other Hymenoptera; but Dr. Taschenberg thinks that it is simply for the purpose of having the materials at hand for the purpose of closing up the nest when finished and stored. It may probably serve both purposes. The provisions carried into the nest when completed consist of small larvæ of Beetles or Lepidoptera. The insect grasps her booty with her jaws near the head, holds it under her body by means of her legs, flies with it to the nest, and conveys it to the further end of the cavity, where it is carefully packed away, curled into a ring-like

form, its power of movement having been paralysed by the sting of the Wasp. Other larvæ are brought in until a sufficient supply has been accumulated, when an egg is deposited with them and the nest closed up. Other species of the genus have similar habits, and those which form their nests in dead and rotten wood, bramble sticks, and similar situations, follow much the same mode of life, except that they frequently divide their nests into several cells by earthen partitions. The larvæ stored in the nests generally belong all to the same species.

The species of the genus *Eromenes* and its allies have the first segment of the abdomen very slender towards its junction with the thorax, enlarged behind, and then again slightly constricted, so that it has somewhat a pear shape, whence the only British species was named by Linneus *Vespa coarctata*. This species, which is not uncommon on the continent of Europe, although scarce in Britain, constructs small globular nests of mud about the size of a hazel-nut, and attaches them either to the twigs of shrubs or to the surfaces of rocks and walls. These nests are stored by the female with small green larvæ, and it is supposed that two broods are produced in the year.

A few species, forming the group *Masarides*, which chiefly inhabit warm countries, are distinguished by having only two submarginal cells in the fore wings, which are also often only partially capable of being folded. Two species (*Celonites apiformis* and *Ceranius fonscolombi*) occur in Southern Europe.

FAMILY CRABRONIDÆ.

This family includes a considerable number of more or less wasp-like insects, often presenting the same livery of yellow and black that is so common among the solitary Wasps, but occasionally showing a red and black coloration, reminding us of the insects of the next family. The Crabronidæ (or Sphegidæ—as they are sometimes called) may, however, be distinguished from the members of both these families by the circumstance that the prothorax is not produced at the sides so as to reach the bases of the fore wings, but reduced to the ring-like structure that we have already stated to be characteristic of the Hymenoptera generally; and as a further difference from the true Wasps, it must be noted that their wings are not capable of being folded longitudinally. These insects never form societies, and all the individuals are therefore either true males or true females; the antennæ are generally short, and not geniculated; the eyes are generally oval, and the ocelli distinct; there are from one to three sub-marginal cells in the fore wings; the tibiæ and tarsi are spinous.

In their habits, the Crabronidæ present a considerable resemblance to the Solitary Wasps. The females deposit their eggs in cells which are usually formed in the ground at the extremity of a passage of some length, but sometimes in dead or decaying wood, or in the branches of brambles, and other shrubs or trees, or built of earthy materials against walls, &c.; and the food of the larvæ consists of various insects, which the mother generally paralyses by stinging them in the belly, so as to pierce the nervous cord, and then packs into the cell in sufficient quantity to supply her offspring with nourishment until it attains its full development. The egg is then deposited, and the nest closed. The victims belong to various groups of insects, and include small larvæ of Lepidoptera and Beetles, and Grasshoppers, perfect Beetles, Flies, and even Bees, besides Spiders, &c. Some species, instead of rendering their prey helpless by stinging them, kill them outright by a severe bite. These latter do not store and close their cells, but leave them open, and bring in fresh supplies of food until the larva is full-grown. Here also, as among the Bees, we find some Cuckoo-like types, which make no nests, but deposit their eggs in the cells prepared by their more industrious relatives.

The typical genus *Crabro* is a very extensive one, including over 150 species, a great proportion of which are inhabitants of Europe, while even Britain possesses more than thirty-five. They are black and yellow insects of small and moderate size. They have only a single sub-marginal cell in the fore wings, and the males in many species have the anterior tibiæ and part of the tarsal joints dilated into curious plates, which are sometimes apparently perforated like a sieve, a character which has gained the largest of the British species the name of *Crabro cribrarius*. This species, and many others, burrow in the ground, generally in hard sandbanks, and provision their nests with Gnats and other Dipterous insects. One species (*C. brevis*), which frequents the same situations, has been found to carry in small Beetles of the genus *Haltica*; and another, which was observed making its nests in the mortar of old walls, provisioned them with *Aphides* from the rose. Many species,

including *C. sexmaculatus* and *C. vagus*, which are very abundant in Britain, make their burrows in decaying wood, old posts, and the dead trunks of trees, and also show a preference for Dipterous Flies. A few occupy the pith cavity of bramble and rose sticks with their little cells.

The species of *Cerceris*, which have the junctions of the abdominal segments strongly constricted, for the most part collect small Beetles as a provision for their larvæ, Weevils of various kinds being apparently preferred. Some of the exotic species are of considerable size—upwards of an inch in length—and of great beauty. One of them attacks species of Buprestidæ, and another provisions its nest with Honey Bees. The great enemies of the Bees, however, are the species of the genus *Philanthus*, which are numerous, and distributed nearly all over the world. There is one British

species (*Philanthus triangulum*), which is very local in the country, and forms its burrows in sandy places. In the Isle of Wight Mr. Smith observed it provisioning its nest with hive Bees, and two species of Andrenidæ. This insect (which has also been called *Philanthus apivorus*, from its Bee-eating habits) lies in wait for its victims among the flowers which they frequent, and, on their settling in search of honey, dashes upon them, seizes them with its strong mandibles between the head and the thorax, and stings them in the abdomen. The Bee, being thus rendered quite helpless, is grasped by the jaws and legs of its assailant, and immediately carried off to be deposited in the nest of the latter. The nest is a



PHILANTHUS TRIANGULUM AND NEST.

tunnel made in some bare sandy spot, often in a path, carried down for some distance, more or less perpendicularly, and then turned horizontally parallel to the surface.

The large species of the genus *Sphex*, some of which grow to a length of about two inches, make war upon the Grasshoppers which abound in warm sandy places. These insects, in attacking their bulky prey, use every endeavour to turn the Grasshopper on his back. When they succeed in this they clasp his long hind legs with their fore feet, and standing over him inflict two stings, one in the neck and the other in the suture between the pro- and meso-sternum, and these soon paralyse the victim, which is then dragged to the nest of its ruthless destroyer. *Sphex flavipennis*, a well-known species of the south of Europe, furnishes each nest with about four Grasshoppers, the soft interior parts of which are speedily devoured by the voracious larva, the hard, chitinous skin being left almost uninjured.

In several tropical species of *Cerceris* and *Philanthus* the first segment of the abdomen is much elongated, forming a long slender footstalk; in another genus of these Sand Wasps (*Amnophila*)

which is perhaps the most widely distributed of any, and of which two species are exceedingly abundant in Britain, the petiole of the abdomen is similarly elongated, and in some species the first two segments take part in its formation. This is the case in the common British Sand Wasp (*Ammodiplosa sabulosa*), a formidable insect nearly an inch in length, having the head and thorax black and hairy, the second and third segments of the abdomen red, and the remainder black. The abdomen is strongly clubbed. This insect is very common in sandy places, and stores its nest with Caterpillars, of which the female under favourable circumstances lays in a store of three or four according to their size in each cell. She stops the entrance of her burrow with a small heap of stones after depositing each Caterpillar, and should bad weather intervene before the whole necessary store has been accumulated, she will bring in further supplies as soon as the opportunity offers.

Ammodiplosa hirsuta, another British species, with a shorter abdominal petiole and a more hairy surface than the preceding, is said by Mr. F. Smith to provision its nest with spiders. This is the case also with another long-stalked species (*Pelopæus spirifex*), which occurs commonly in central and southern France and other countries bordering the Mediterranean, and differs from all that have been hitherto noticed by its habit of building a nest of clay, containing several cells, in sheltered situations, about walls, barns, and houses. The female builds cell after cell, storing them with Spiders and laying an egg in each as she completes them. *Pemphredon lugubris*, a very common small European and British species, of a uniform black colour, burrows into decaying wood and in bramble sticks, and stores its cells with Aphides, which it collects and scrapes together into a ball in a most unceremonious manner.



PELOPÆUS SPIRIFEX AND NEST.

FAMILY POMPILIDÆ.

The Pompilidæ agree in general structure, and also in habits, with the insects of the last family, with which and the two following families they used formerly to be grouped under the name of Fossorial or Digging Hymenoptera, from their general practice of digging burrows for the reception of their eggs. The chief point of difference between the Pompilidæ and the Crabronidæ consists in the structure of the prothorax, which in the former is produced on each side as far as the root of the wings—as in the True Wasps—but the wings are incapable of being folded longitudinally, and they are generally large and broad, with three sub-marginal cells. The antennæ are long, and not

kneec; the eyes are not notched within; and the legs are long, with spinose tibiæ, which have long spines at the apex. There is no striking difference between the two sexes. There are some 700 or 800 known species, and they occur in all parts of the world, the range of the typical genus (*Pompilus*) extending from Lapland to the Cape of Good Hope, and from China to Chili. Many tropical species are of large size and great beauty, some of them being adorned with bands of silvery pile, and having the wings richly coloured.

Most of the species of *Pompilus* burrow in sand, or sandy soil, and store their nests with Spiders and the larvæ of insects—generally the former—with which they wage constant war, and it would appear that as a rule the females of each species show a decided preference for certain kinds of victims in storing their nests. Their behaviour with large spiders shows great boldness. They attack their intended prey vigorously and continuously until, apparently in despair, the Spider throws himself upon his back, when he contrives to repel the assaults of his enemy for a time by the action of his legs; but on his becoming exhausted the Wasp dashes in upon him, seizes him with her jaws beneath the breast, and speedily paralyses him by two or three stings in the abdomen. The Wasp then, after inspecting her victim on all sides, to make sure of its being in a helpless condition, seizes it by the fore part of the body, and drags it away to her nest. Smaller Spiders and Caterpillars naturally give less trouble.

One of our commonest species, the *Pompilus fuscus*, is usually about half an inch long, and is black, with the first three segments of the abdomen red, and banded with black. The wings are brownish, with the tips black. This insect makes its appearance in the spring, and may be observed in sandy places throughout the summer. It burrows in the sand to a depth of three or four inches, digging out the sand with its fore legs after the fashion of a terrier dog. It is said to provision its nest with various supplies, but prefers Spiders. Some species, which have the anterior tarsi destitute of the fringes of bristles, construct cells of mud very similar to those of *Pelopæus*. The British *Pompilus punctum*, a small black species, is one of these.

The species of *Ceropales*, which also have no fringes on the tarsi, and the legs almost destitute of spines, are further remarkable for having the posterior legs unusually long, and are believed to act the Cuckoo part—depositing their eggs in the nests of other Pompilidæ. Although not numerous in species, the genus is very widely dispersed over the face of the earth. Two species occur in Britain.

Pepsis is a peculiarly American genus, its species being almost entirely confined to South America. Most of them are of large size and great beauty. *Pepsis heros*, a species found in Cuba, attains a length of two inches, and is of a deep black, with a dark blue lustre on the head, abdomen, and legs—whilst the wings are reddish, with a metallic tinge and a dark brown margin.

FAMILY SAPYGIDÆ.

This is a small family, containing only a single genus, with very few species. Like the Pompilidæ the insects referred to it have the prothorax produced to the base of the wings on each side, a character which also occurs in the next family; but the legs are destitute of spines, the hind legs do not extend beyond the tip of the abdomen; the antennæ are long, and usually more or less clubbed; the eyes are notched on the inner margin; and the sexes are alike in form, both being winged. The species of *Sapyga* occur in Europe and North America. They are supposed to be parasitic in the nests of Bees, and the females are found in the neighbourhood of the burrows of the latter; but the females of the common European and British species (*Sapyga pæca*, or *punctata*) have been observed carrying small Caterpillars, from which Mr. Smith, with justice, infers that they are parasitic only to the extent of usurping the burrows made in sandbanks and dead wood by more industrious insects, their own structure not adapting them for the labour of digging. The species above mentioned, which varies between one-third of an inch and half an inch in length, is black, with the abdomen partly red in the female, and both sexes have transverse white spots on some of the abdominal segments. This species haunts the nests of species of *Osmia*. The largest species of the group (*Sapyga repanda*) is similarly attached to the great Carpenter Bee (*Xylocopa*).

FAMILY MUTILLIDÆ.

In this family, which completes the series of so-called Fossorial Hymenoptera, we still find the prothorax extending at the sides to the base of the fore wings when these are present; but the males

and females differ greatly from each other in many respects, the latter being often destitute of wings, or having those organs greatly reduced in size, whence the name *Heterogyna* has been given to the group by many entomologists. In both sexes, however, the legs are comparatively short and hairy, or spinose, but with long tarsi; the eyes are notched on the inner margin; and between the first and second segments of the abdomen there is a notch or constriction. The group includes a large number of species—probably 1,200 or 1,300—but from the differences presented by the males and females entomologists have found it difficult to arrive at any certainty upon this point. The species are spread over all the earth, but are particularly abundant in warm climates, where also, as usual, they attain the largest size and the most beautiful colouring.

In the genus *Mutilla*, from which the family name is derived, and in the allied genera, which include the great bulk of the species, the peculiarities of the group are most strongly marked, and the differences between the sexes so striking that until comparatively recent times the males and females, even of well-known species, were referred to distinct genera, and sometimes rather widely separated. Of *Mutilla* some 500 species are known from all parts of the world, and three of them occur in Great Britain. They are found usually in sandy spots. In this genus the females have no ocelli. The most abundant European and British species (*Mutilla europæa*) is about half an inch long, of a black colour, hairy, with the thorax entirely red in the wingless females, red in the middle in the winged males; the abdomen has three transverse bands of white or yellowish hairs, the two hinder of which are interrupted in the middle. The wings of the male are brownish. The females of this and other species have an aspect intermediate between that of a Spider and that of an Ant, whence the German entomologists give them the very characteristic name of "Spider Ants." The habits of the species are not very well known. The *Mutilla europæa* frequents the nests of Humble Bees, and its larvæ appear to be parasitic upon the larvæ of the Bees. Mr. Drewsen of Copenhagen obtained only two Worker Bees from a nest of *Bombus skrimshiranius* taken by him, which furnished seventy-six examples of

Mutilla europæa, forty-four males and thirty-two females. The larvæ of the *Mutilla* were found in the cocoons which had been formed by the full-grown larvæ of the Bee. The females, after impregnation, pass the winter rolled up in the ground or under stones. Both sexes of this and other species can produce a faint chirruping sound by the friction of the third and fourth abdominal segments upon one another; and the special arrangements for producing this noise consist of a small triangular finely-ribbed area upon the upper



MUTILLA EUROPÆA.

surface of the fourth segment, over which passes the hinder margin of the third segment, furnished beneath with a little sharp ridge. These parts are rubbed together by the extension and retraction of the fourth segment, which slides in and out of the third like the draw-tube of a telescope.

A great number of species of *Mutilla* occur in South America, which is also the home of another important genus (*Thynnus*), likewise largely represented in Australia.

In another group of the family, formed by the genus *Scolia* and its allies, the female is winged.

and generally presents rather less divergence from her partner than in the more typical genera just referred to. Nevertheless, there are important differences between the sexes; the male has long and nearly straight antennæ, while those of the female are short and bent; the female is generally larger and more robust than the male; and they frequently differ in coloration, sculpture, hairiness, and other characters to which we cannot here refer. The *Scolie* are large and powerful Hymenoptera, some of them attaining a length of two inches, and they are armed with very formidable stings. They chiefly inhabit warm countries, and their larvæ usually feed upon the grubs of large Beetles.

The British forms of this group belong to a distinct genus (*Tiphia*), and are of small size. They are not abundant. Mr. F. Smith notices the frequent occurrence of the commonest of them (*Tiphia femorata*) under the droppings of cattle, from which he was led to suspect that they might be parasitic upon the larva of some coprophagous Beetle.

FAMILY FORMICIDÆ.

In this family, which includes the various species of Ants, we have to do once more, and for the last time, with social insects organised after the fashion of the Bees and Wasps—that is to say, in which the community is permanently made up of infertile females, or workers, with one or more perfect females for egg-laying purposes, and only at a certain season of a larger number of females and males. As in the case of the Hive Bee, the communities of Ants are generally permanent. The economy of these insects presents some of the most interesting phenomena that the study of zoology has to offer, and the writer's difficulty is to select from the mass of materials extant what will suffice to give some notion of the natural history of the group.

Even the character that must be given of the family is a complex affair. The males and females are winged on their emergence from their cocoons; the workers are always wingless. After the nuptial flight the males die, and the females drop, or even pull off their wings; but the latter have the thorax broad, and of the ordinary Hymenopterous type, with the meso-thorax much developed for the support of the large anterior wings. In the workers, on the contrary, the whole thorax is slender, and the prothorax is the most developed segment. In the males and females the head is comparatively small; in the workers larger; and in many cases two forms of workers exist—one with a head of ordinary size, the other with this part wholly out of proportion to the rest of the body, and armed with formidable jaws. These large-headed workers are commonly called "Soldiers," and their function is supposed to be to fight in defence of the nest. The antennæ are generally kneed, with a long first joint, except in the males of some types, in which the first joint is not much elongated, and the geniculation is inconspicuous. The eyes are large in the males and females, always small and sometimes rudimentary in the workers; and the ocelli, which are always present in the males and females, are generally entirely wanting in the workers. In the wings, there is usually only one submarginal cell, never more than two. The first, or first and second, segments of the abdomen form a stalk, or *petiole*, very distinctly separated from the rest of the abdomen, which is ovate, heart-shaped, or sub-globular in form; and these segments bear a knot, or transverse scale, the presence of which is one of the most easily-recognisable characters of the family. The females and workers frequently possess a regular sting, which they use vigorously in their own defence. Others have no

sting, but most of these possess glands, secreting an acrid fluid containing formic acid, which they can inject into the wounds produced by their mandibles.

The Ants are generally small and often minute insects, which swarm in all parts of the world, but are most abundant, both in



species and individuals, in tropical countries, where also the largest forms occur. The number of described species is probably over a thousand, but the total number must be considerably greater, if Mr. Bates is correct in his estimate that not less than 400 species inhabit the valley of the Amazon.

The general habits of the species may be succinctly described as follows. The nests are almost always chambered cavities, hollowed out either in the ground, in walls and similar situations, or in dead and decaying wood. A distinguished Swiss naturalist, M. Forel, has classified the different kinds of nests made by the Ants of Switzerland, and his observations will generally apply equally to those of other countries. He describes the following categories:—1. *Ground nests*, consisting either of galleries burrowed in the earth, sometimes exposed, sometimes protected by being made under a stone, or of similar galleries and chambers, surmounted by a chambered hill, built up of the materials removed from the subterranean dwelling. One of the commonest examples of this series is the common GARDEN ANT (*Formica nigra*), which may be found everywhere in gardens, making its nest in the ground, but often taking advantage of an inverted flower-pot to throw up under cover a mass of fine mould, traversed by chambers and galleries in all directions. Another is the pretty little TURF ANT (*Formica flava*), which generally haunts commons and heaths, casting up small hills, which serve to throw off the rain, and this species in some localities makes its nest under stones. 2. *Wood nests*, consisting of chambers and galleries hollowed out by the insects in the substance of trees, posts, &c. The course followed by the Ants in the excavation of their dwellings in wood seems to be governed, to a certain extent, by the direction of the fibres of the wood. The WOOD ANT (*Formica ligniperda*) practises this method of architecture. Some minute Ants, forming the genus *Leptothorax*, bore into the bark of trees, and there make their nests, consisting of a few chambers. 3. *Paper nests*, of which the only Swiss examples are those of the JET ANT (*Formica fuliginosa*), a well-known British species, which is provided with greatly-developed salivary glands, secreting a very tenacious fluid, by means of which the Ants produce a sort of cardboard from masticated wood-dust, and use this in the fabrication of their dwellings. Their nests are usually situated in stumps of trees. 4. *Composite nests*, of which those of the WOOD ANT (*Formica rufa*), so common in our woods and forests, may serve as an example. The nests of these insects, as is well known, consist of a great heap of small fragments of sticks and other vegetable substances most artificially put together so as to form the necessary galleries and chambers for the economy of the community. M. Forel also refers to this class, the nests made in rotten tree-stumps, in which the extremely decayed wood is used in the same way as the earth by other species for the construction of their dwellings. 5. *Divers nests*, or those which cannot be brought under any of the preceding definitions, such as the dwellings formed by Ants in the fissures of walls and rocks, in houses, &c.

The size of the nest depends upon that of the community to be sheltered by it, and in the larger ones the complication of passages and chambers in several storeys becomes very great. Certain passages lead directly to the surface of the nest, where there are openings permitting the egress and ingress of the inhabitants, but these are in general carefully closed at the approach of night. Besides these simple doorways, many species make passages leading out of the nest, sometimes to a considerable distance, which serve as covered ways for the Ants in going to and from their favourite feeding grounds.

Although the communities of Ants are permanent, the males of course are only to be found in the nests for a certain time, but in the case of some species this period seems to be much longer than in the Social Bees and Wasps. In many instances the females also disappear after depositing the last batch of eggs of the autumn season, and thus the nest in the spring contains only workers with larvæ and pupæ. The larvæ of this last brood are carried down by the workers into the deepest recesses of the nest, where they pass the winter in a state of torpidity. In the majority of species, however, the females appear to survive from season to season, but it is not believed that they live more than one year. The eggs and larvæ are carefully attended to by the workers, the latter being fed by them, and both being carried from one part of the nest to another, so as to be placed always in the most favourable conditions for their development, or conveyed into the penetralia of the nest should any danger threaten the community. Later on the larvæ become converted into pupæ, many of them first enclosing themselves in a small silken cocoon.* The pupæ are still the

* The group of the Myrmicinae, characterised by having two knots or scales in the petiole of the abdomen, includes species which usually spin no cocoons. In the rest of the family (Formicinae), although the formation of the cocoon is the rule, it is liable to many exceptions, and, indeed, pupæ with and without cocoons are said to occur in the same nest. The pupæ in cocoons are the objects commonly known as "Ants' eggs," and sold under that name as food for the soft-billed singing birds.

objects of the most assiduous care on the part of their foster-mothers. From them are produced new workers, and in the course of the summer a number of winged males and females, which remain in the nest until their instincts tell them that the conditions of weather outside are favourable for them to take their nuptial flight. The several individuals of the same species over a considerable district generally fly out on the same day, and in this way often produce the effect of dark clouds, especially when, in obedience to an instinct that prompts them to hover about an elevated object, they select the summit of the steeple of a church or of some lofty tower as a place of rendezvous.

Of course, during these vagaries immense numbers of the insects fall a prey to birds, and those of the males which escape this fate probably perish soon after their return to the ground. The females, on the other hand, after their descent, may be seen running about with their wings in a more or less dislocated condition. The wings, in fact, drop off, or are pulled off very soon after the females reach the ground, and they then either establish a new nest after the fashion of the Wasps and Humble Bees, or find their way into an established nest of their own species. These fertilised females then furnish eggs for the continuance of the species, and the larvæ hatched from them are fed and cared for by the workers, as already described.

The duties of the workers are, in fact, as multifarious as those of the worker Bees. They have the care of the construction, maintenance, and enlargement of the common dwelling, and upon them also depends its defence from enemies, in which they display the greatest courage and determination. As already mentioned, in some species there is a special kind of worker (soldiers), whose supposed duty it is to protect the nest from invaders, and in these the head is very large, and the mandibles correspondingly powerful; but even the ordinary workers are exceedingly courageous when called upon to defend their home. A further duty is the bringing in of provisions, and in this the workers are indefatigable. Their food consists of both animal and vegetable matters, and, like the Bees, they are particularly fond of saccharine substances, which they obtain from flowers and fruit, and also from the Aphides, or Plant-lice. These insects secrete a sweet fluid, which flows in the form of clear drops from two small tubules placed on the sides of the abdomen near its extremity; these drops the Ants greedily suck in, and they have the art of inducing the Aphides to produce further supplies of the same liquid by gently stroking them with their antennæ, a process which has been not inaptly compared to milking. Of animal food, scarcely anything comes amiss to them; the flesh and other soft parts of small dead animals that may chance to lie near the nests of Ants are speedily cleared away; and many tropical species immediately attack and destroy insects much larger than themselves, overcoming all their struggles by mere force of numbers. The larvæ are fed upon drops of fluid disgorged by the workers.

The labours of the workers on behalf of the young are not, however, limited to feeding them. In fine weather, and in the middle of the day, the larvæ and pupæ are brought into the more superficial chambers of the nest, or even sometimes quite outside of it; at the approach of night, or of bad weather, they are conveyed to the most deeply-seated apartments, where they may be protected from injurious influences. The anxiety of the workers for the safety of their helpless charges is always strikingly manifested in the case of any injury to the nest. If a portion of the outside be broken down, a crowd of workers instantly rush to the breach, a part of them setting to work at once to repair the damages, while others immediately seize upon any larvæ and pupæ that may be mingled with the ruins, and bear them off in their mandibles to a place of safety.

There are so many remarkable facts known about these most interesting insects, that one is embarrassed in selecting what will serve best for the completion of the general sketch of their history, which is all we can hope to give here. One very singular fact is that although it has been repeatedly proved that the inhabitants of a nest will severely maltreat and even kill individuals of the same species belonging to a different nest, which may by chance intrude into their dwelling, not only may nests belonging to the same species be found in juxtaposition upon the same piece of ground, and furnished with passages establishing free intercommunication between the separate nests, but in a great many cases colonies of different species inhabit the same nest. Thus *Stenamma westwoodi*, a small species of the double-knotted group of Ants, has never been met with except in the nests of the great Wood Ant (*Formica rufa*) and an allied species (*F. congestus*); and although nothing appears to be known of the nature of the connection between these two seemingly incongruous

creatures, we must assume that it is in some way necessary to the smaller species. The Turf Ant (*Formica flava*) is often found occupying one side of its hillock, with a colony of another Myrmicine Ant (*Myrmica scabrinodis*) comfortably established on the other; and other species have been met with residing in strange nests, although they are known to form independent colonies.

A still more curious form of association is that in which certain species of Ants keep the workers of other species to act as their slaves. The Warrior Ant (*Formica sanguinea*), a species not uncommon in some parts of England, is one of these, keeping workers of *Formica fusca*, *F. cunicularia*, and *F. flava* in its nest; but in this case "the institution" appears to be needless, as the workers of *F. sanguinea* take their share in the labours of the community. In this, as in the other cases of the same kind, the slave-making Ants make a descent, after the old robber fashion, upon the societies of the species whose services they are in the habit of usurping, and carry off the larvæ and pupæ to their own nest. The workers produced from these set to work to perform the necessary duties of their new home, just as if it was their proper dwelling-place. With the Amazon Ants, indeed, the imported workers have more to do than they would have had in their own community, for the Amazons are so lazy that they will not even feed themselves, and would perish of starvation if they were not fed by these imported workers.

Besides these stranger Ants, other insects are found in the nests of many species, the presence of which is not easily accounted for. The larvæ of the Rose Beetle (*Cetonia aurata*) is found in the nests of the Wood Ant, where it is said to feed on the rotting fragments of wood forming the lowest part of the nest. Species of the Coleopterous genus *Hister* and Brachelytrous Beetles are met with in Ants' nests, and many of the latter have never been found elsewhere. Several Beetles of the curious family Paussidæ have been found in Ants' nests, and, from the circumstances, it would seem that this is their natural habitat. In Europe a great number of the rarest Beetles are also inhabitants of these nests. According to Dr. Taschenberg, more than 300 species of true Ants' nest insects, chiefly Beetles, are known in Germany, and of these, 150 are found with the Jet Ant, and 100 with the Wood Ant.

We have already alluded to the fondness of Ants for the sweet fluids excreted by the Aphides from the so-called honey-tubes which project from the sides of the hinder part of their abdomen. In search of these insects, the Ants roam over every part of the trees and plants infested by them, and, not content with imbibing the nectar spontaneously exuded, stroke the Aphides with their antennæ, lick them with their tongues, and coax them in every way to furnish a further supply. Hence the Aphides have been denominated the milch-cows of the Ants; and, as if to make the comparison more complete, the latter frequently set up a right to exclusive property over the Aphides in their neighbourhood. Sometimes this is done simply by making a convenient covered way leading from the nest to the pasture where the Plant-lice are feeding. Sometimes the Ants build a wall, or even a roof, for the protection of their diminutive flock; and, still more frequently, they carry off a number of Plant-lice, and keep them in their subterranean nests, where they feed by sucking the juices from the roots of grasses and other plants in the neighbourhood of the nest.

It will be easily understood that to carry on all these operations for the general weal a considerable amount of organisation is requisite, and this can hardly be attained without some means of communication between the different members of an extensive community which have to work together for a common end. The doings of the Ants sufficiently prove that they possess some means of conveying intelligence to one another, and, so far as can be made out, while mere pulling and pushing serve for some rough purposes, the finer and more particular communications are made by the agency of the antennæ. These organs seem to come into play in almost all circumstances of Ant life; and all writers upon these insects, from the days of Huber downwards, have devoted much of their attention to this most interesting subject. To enter upon it here, however, would lead us into details, for which space is wanting; and we would particularly refer the reader who wishes for more information to the admirable papers by Sir John Lubbock, published in the *Proceedings of the Linnean Society*. The antennal language, whatever may be its nature, would appear, however, not to be the sole means of communication possessed by Ants. Dr. Lindsay has been induced, by the consideration of the fact that the Spider Ants (*Mutilla*) have the means of producing sounds by the grating of the edge of one abdominal segment over a finely striated portion of the succeeding one, to examine some species of

Ants in search of a similar arrangement, and found in *Ponera* distinctly developed stridulant organs of the same type as in *Mutilla*, and capable also of producing sounds perceptible by the human ear.

The Formicidæ may be usefully divided into two great groups, namely, the Formicine, so named from the typical genus *Formica*, in which the abdominal petiole has only a single knot, or scale; and the Myrmicine, including the great genus *Myrmica* and its allies, which have two knots, or scales, on the petiole. Of British species of the former group, we have already referred to several, such as the Great Wood Ant, the Warrior Ant, the Jet Ant, &c. The WOOD ANT (*Formica rufa*), which is an exceedingly abundant species, has the head and thorax of a rusty-red colour, with a brownish-black tinge in parts, while the legs and abdomen are almost entirely of the latter colour. The largest workers measure more than a quarter of an inch in length, and the females as much as five lines. This species is found in woods, where it lives in a great heap of vegetable fragments, portions of wood and leaves, small sticks, and the needles of pine trees, beneath which the nest is continued in a great extent of subterranean passages and chambers. In favourable situations these nests attain great dimensions: they may be found more than six feet in diameter, and four or five feet high. Like the other species of the genus, this Ant possesses no sting, but the glands producing the acid secretion are well developed, and it appears to be used not only by injection into wounds inflicted by the mandibles, but also by being ejected, after the fashion of that of the Bombardier Beetles, for the purpose of keeping an enemy at a distance. The WARRIOR ANT (*Formica sanguinea*) is less common in England than the preceding species. It has the head and thorax of a blood-red colour, instead of rusty-red, and the legs are red. The largest workers attain a length of a third of an inch. Its communities are smaller than those of the Wood Ant, and its nest is frequently constructed in banks. Its habit of making slaves has already been alluded to. The Wood Ant seems to inhabit the greater part of the Northern Hemisphere, and other European species are widely distributed. Other regions, however, have their own peculiar species, and they are particularly abundant in tropical countries, where also they attain a larger size. One of the largest species is the GIANT ANT (*Formica gigas*) of the East Indies, of which the female measures an inch long. Some of the species of a nearly-related Indian genus (*Polyrhuchis*) are remarkable for making a curious little nest in a curious situation. Mr. T. C. Jerdon, speaking of one of them (*P. nidificans*), says:—"This Ant makes a small nest about half

an inch, or rather more, in diameter, of some papyraceous material, which it fixes on a leaf. I have opened two, each of which contained one female and eight or ten workers."

A very singular species of this group, of which only workers are known, is a Mexican insect, described under the name of *Myrmecocystus*



MYRMECOCYSTUS MEXICANUS (Natural Size and Magnified).

cocystus mexicanus. The workers are of two forms—namely, ordinary Formicine small workers, which appear to perform the labours of the community; and a larger form, to the peculiarities of which the name of the genus refers, in which the abdomen is greatly inflated and nearly transparent, but bears upon its surface horny plates, indicative of the segments. These peculiar workers, which are very inactive, seem to have as their sole duty the secretion of a peculiar kind of honey, which they are said to discharge into receptacles.

The genus *Ponera* and its allies, in which the petiole still has only one knot, but the females and workers are armed with stings, include many species of larger size than those hitherto referred to. They are mostly inhabitants of tropical countries, and their history is very imperfectly known. To this group belong the DRIVER ANTS, or VISITING ANTS, of West Africa, generally referred to the species *Anomma arcens*, although many entomologists are of opinion that other Ants may have the same habits. The workers of *Anomma arcens* grow to a length of nearly half an inch, and are

destitute of both eyes and ocelli. They are described as marching in vast armies, and by some writers as having no settled place of abode. On their march, which is performed on cloudy days and in the night, they drive everything before them, and destroy not only all the insects they meet with, but even many larger animals, which they are said to attack first of all in the eyes. In this way even large snakes are described as becoming their victims. When they come into the negro villages, and make their way into the houses, the inhabitants are obliged to quit their dwellings, and wait until the Ants have passed. But their visits are attended with certain benefits, which render them not altogether unwelcome. Their appearance in a house is soon revealed by the simultaneous movement of all the rats, mice, lizards, cockroaches, and other vermin which swarm in the dwellings in warm climates, and these are either compelled to decamp hastily, or are caught, killed, and devoured. The Drivers are said to cross rivers by a portion of them making themselves into a living bridge, over which the others pass in safety. When dislodged from their lurking places by sudden floods, they are described as making themselves into a rounded mass, with the pupæ and eggs in the centre, and in this form they float upon the water until they are landed in a safe place, or the flood subsides.



SAUBA ANT.

Of the second group of Ants (the Myrmicine), the best known species are the little RED ANTS (*Myrmica ruginodis*, *scabrinodis*, and *lvinodis*), formerly included under the general name of *Myrmica rubra*. The workers are generally about a sixth of an inch long, and the males and females rather larger. They are met with making their nests in the ground, under stones, in the stumps of trees, &c., and often occur in immense numbers. A very minute Ant, which has been introduced into Great Britain probably from Brazil or the West Indies, is the HOUSE ANT (*Myrmica molesta*). It is a very small brownish-yellow species, which seems to have been first observed in England in 1828. It takes up its abode in houses, frequently in the neighbourhood of the kitchen fireplace; and, when it multiplies, becomes such a pest as to render the house uninhabitable.

This group includes a multitude of interesting exotic species, mostly of larger size than the European forms. In the genus *Eciton*, the species of which are found almost exclusively in Brazil, the workers make expeditions in long and regular columns, pushing out branch columns in the direction of any promising locality. These processions, one of which was observed of a length of from sixty to seventy yards, without either the front or rear of it being visible, are doubtless made commonly for foraging purposes, but singularly enough the insects frequently carry the larvæ in their mandibles. Any insects falling in the way of these expeditions are immediately seized and torn to pieces. *Ecodoma cephalotes*, the SAUBA ANT, also a Brazilian species, lives in enormous communities in subterranean fornicaries, the position of which is indicated externally only by a low hill of earth, of rather light colour. These Ants are leaf-cutters, ascending the trees in vast numbers, and cutting pieces out of the leaves about the size of a shilling, which are dropped to the ground, where another multitude is incessantly engaged in gathering up the pieces, and carrying them to the nest. For what purpose these portions of leaves are so laboriously collected it is difficult to say. Mr. Belt thought that the Ants stored them in subterranean chambers for the sake of the fungi which grew upon them there. The *Ecodoma* is not content with such diet, however, but becomes a nuisance in Brazil, by visiting the houses for the purpose of plundering provisions.*

FAMILY CHRYSIDIDÆ, OR GOLDEN WASPS.

Some brilliant little gems of flies, showing the colours of the emerald, the sapphire, and the ruby, with the addition in general of a golden surface tint, form the last family of the Aculeate Hymenoptera. These insects have the antennæ composed of thirteen joints, and bent at the end of the first joint, the eyes oval, and the ocelli distinct. The mouth is constructed after

* For further information on the European Ants the reader may consult the writings of Francis Huber, Latreille, and other older writers, or the summary of their results given in the "Introduction to Entomology" of Kirby and Spence. Sir John Lubbock's valuable papers have already been referred to. Upon exotic Ants, interesting notes will be found in the writings of several travellers, but especially in Mr. Bates's "Naturalist on the Amazons," and Mr. Belt's "Naturalist in Nicaragua." Mr. McCook's articles on Californian and Mexican Ants, published in the "Proceedings of the Academy of Natural Sciences of Philadelphia," are also most interesting.

the usual mandibulate plan, with five-jointed maxillary and four-jointed labial palpi, but the labrum is very small and concealed. The general form of the body is somewhat cylindrical, and it is enclosed in a very hard skin; the abdomen, which is attached to the thorax by a short petiole, shows externally three or four segments, of which the second is very large, and its lower surface is generally hollowed out so as to enable the insect to form itself into a sort of ball after the fashion of a hedgehog or woodlouse. The hinder margin of the last segment is usually toothed, and the number of teeth is often useful in distinguishing the species. Besides these apparent segments, however, the abdomen possesses two or three more, which form a sort of telescopic tube, capable of being retracted within the abdomen, and at the extremity of these is a sting, which, although minute, is able to inflict painful wounds. The venation of the wings is much more simple than in any of the preceding families; there is only one submarginal cell, and even this is not closed.

These insects are of small size, comparatively few of them exceeding half an inch in length. The number of known species is probably between 400 and 500, and they occur in most parts of the world, but are decidedly more plentiful in Europe than elsewhere. All present a very strong family likeness, and their habits are similar throughout the family. About twenty-five British species are recorded, and of these we may take one of the commonest, the *Chrysis ignita*, as the type of the whole. This insect, the Common Gold Wasp, or Ruby-tail, measures from four to five-twelfths of an inch in length, and is of a deep metallic bluish green colour, except the upper surface of the abdomen, which is bright red, with a beautiful golden gloss upon its surface. The whole surface is closely, and more or less coarsely punctured; the thorax is spotted with black; and the apical margin of the abdomen shows four teeth, with a row of ten little pits just in front of them. This beautiful little creature is to be seen almost everywhere during the summer, flying in the hot sunshine, creeping about walls and palings, especially in gardens, and poking its head into every small hole it meets with. This is the female insect, which, when thus occupied, is engaged in looking out for the nest of some Bee or Wasp in which she can lay her eggs. On finding an occupied burrow or nest undefended by the owner, the *Chrysis* immediately makes its way in, and leaves an egg behind her. It appears that the larva hatched from this egg does not make its appearance until the Bee- or Wasp-larva is nearly full-fed; it then attacks and soon devours the latter. The full-grown larva of the *Chrysis* spins a little cocoon within which it passes to the pupa state. Occasionally, when the little Gold Wasp is inspecting the nest of an absent Bee or Wasp, the rightful owner returns, and not unnaturally manifests a good deal of indignation at the intrusion. In such cases the Bee will seize the *Chrysis* with her mandibles, and unceremoniously throw it out of the nest, but the sting of the Bee or Wasp is quite powerless against the hard plate armour in which the parasite is encased. The latter, however, is not easily discouraged; she will make her way back again and again to the nest from which she has been ejected; and when a Bee, losing its temper at the pertinacity of its little enemy, has bitten off the wings of a *Chrysis*, the latter has been seen to unroll itself and crawl up once more to the nest. The finest European species of the family is named *Stilbum splendidum*. It measures from half to seven-twelfths of an inch long, and is usually of a fine blue or emerald green colour, but has the abdomen sometimes golden red. This insect occurs in Southern Europe and throughout Africa and Southern Asia.



METAMORPHOSES OF THE PROCESSIONARY MOTH (*Cnethocampa processionca*) AND OF
CALOSOMA SYCOPHANTA.

CASSELL'S

NATURAL HISTORY

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CASSELL'S NATURAL HISTORY.



ICHNEUMONS (*Pimpla manifestator*). MALE IN FLIGHT, FEMALES ON TREE.

CLASS INSECTA.

CHAPTER VII.

ORDER HYMENOPTERA (*concluded*):—THE ENTOMOPHAGA AND PHYTOPHAGA.

ENTOMOPHAGA, OR "INSECT-EATERS"—Meaning of the Term—THE ICHNEUMONIDÆ—Characters—Immense Number of Species—Parasitism—Habits of various Genera—THE PROCTOTRUPTIDÆ—THE CHALCIDIDÆ—THE CYNIPIDÆ, OR GALL FLIES—Characters—Habits—The Galls—Different Genera—THE PHYTOPHAGA—THE UROCERIDÆ, OR TAILED WASPS—Characters—The Great Tailed Wasp—Habits—THE TENTHREDINIDÆ, OR SAW FLIES—Characters—Various Species.

TRIBE II.—ENTOMOPHAGA.

FAMILY ICHNEUMONIDÆ.

THE term Entomophaga, or "Insect-eaters," does not strictly apply to all the insects included in the tribe so named by entomologists, but so great a majority of them are parasitic in the larva state upon other insects, that the name is a perfectly admissible one. The group may be at once distinguished by the possession of a petiolate abdomen and two-ringed trochanters.

The largest and most important family of this tribe is undoubtedly that of the Ichneumonidæ,

the larvæ of which are all parasitic. In this family, which includes the largest species of the group, we find a great variety of characters, but the insects composing it have the antennæ thread-like or bristle-like, generally long and many-jointed, and the wings with from one to three complete submarginal cells. The body is long and thin, and the abdomen shows at most seven segments. The ovipositor issues from the extremity of the abdomen of the female.

This enormous family of insects is at the same time one of the most difficult to study systematically, and although we know that the number of species must be very great, it is almost impossible to estimate what it may be. It has been calculated that there are not less than 4,000 to 5,000 known species of Ichneumons, but the data are very untrustworthy. They occur in all parts of the world, and their importance in the economy of nature is very great. The females deposit their eggs in or upon the bodies of other insects, especially the larvæ of Lepidoptera and plant-eating Beetles. The



WING OF ICHEUMON.

larvæ hatched from these eggs feed upon the substance of their host, avoiding the vital parts, so that the unfortunate animal goes on assimilating food for the benefit of the parasites dwelling within him until he completes his term of larval existence, and sometimes even attains the perfect state; but sooner or later the parasites either break out of the body of their host, or spin their cocoons within it, with a result that in either case is equally fatal. No stage of the insect's life is safe from these active enemies; they attack all, from the egg to the imago, but the larvæ receive most of their attention. A great number of the species are confined to particular families of insects in the choice of their victims, while others infest only particular genera or even species, and the charge of parasites introduced into the body of an individual host is always proportionate to the relative sizes of host and parasite. Thus the eggs of insects are attacked only by the smallest species of Ichneumons, and only a single egg is deposited in them; the larger Ichneumons also frequently place only one egg in the caterpillars or other larvæ which they attack, and the Ichneumon larva then spins its cocoon within the emptied pupa case of its victim. On the other hand, many small species deposit their eggs in large caterpillars or other larvæ, and then the number of eggs is proportioned to the size of the host, and the Ichneumon larvæ either fill up the empty cocoon with a mass of close-packed cocoons, or break out of the infested larva as it is preparing to change, and spin their cocoons separately around it. But perhaps the most remarkable circumstance connected with this parasitism is that the parasites are themselves subject to be attacked by parasites belonging either to this family or to one of the succeeding ones, the females of these having the instinct to recognise the presence within the host of a parasitic larva, and possessing the art of passing their eggs through the integuments of the former into the latter. We have thus in the history of these insects a series of checks and counterchecks of the most astonishing complexity. As the Ichneumon larva uses up all the material it derives from its host in building up its own body, it naturally grows pretty rapidly, and the host may perhaps be stimulated to increased assimilation by the presence of hungry parasites in its interior. The respiration of the latter is provided for in a curious way; the principal tracheal stems open at the hinder extremity of the body, and this is brought into connection with one of the stigmata of the host, thus opening a free communication with the external air.

The development of the ovipositor is very different in the females of different genera and species of Ichneumons, and this stands in direct connection with their habits. In the females of some forms the ovipositor scarcely projects from the extremity of the abdomen, whilst others have a long, bristle-like organ two or three times the length of the body, and between these two extremes every gradation occurs. The short ovipositors are possessed by species which deposit their eggs in or upon easily accessible larvæ; the long ones characterise those which seek concealed larvæ, such as the grubs of wood-eating Beetles.

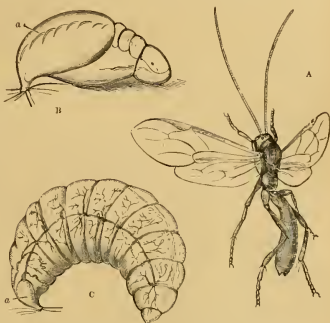
The species of *Ophion*, *Paniscus*, and some allied genera which have long antennæ, only two submarginal cells, a compressed abdomen, and a very short ovipositor, possess a very curious history. They deposit small stalked eggs (see figure), much resembling little seeds, upon the surface of various caterpillars, and these eggs adhere to the skin of the caterpillars by little hooks at the extremity of the stalk. After a time the egg splits into two valves, from between which a minute grub issues, and proceeds at once to push its head through the integuments of the caterpillar, so as to feed upon the

contents of its body. In some cases the Ichneumon larva makes its way within the body of its host, and becomes an internal parasite; in others it remains permanently on the outside, its hinder extremity being always enclosed between the valves of the egg-shell, and then, its body being very translucent, the transfer of the substance of the host to the parasite may be observed going on very actively.

In the genus *Evania* and its allies we find a very curious arrangement. The abdomen, instead of springing from the back of the thorax immediately above the hinder coxæ, is lifted up, so that its thin petiole is attached just beneath the back of the metanotum. In *Evania* the abdomen is so small as to appear only like an appendage to the thorax; hence the best-known species has been named *E. appendigaster*. It is a small black insect found in the South of Europe and in all tropical countries. It is parasitic upon Cockroaches. An allied British genus (*Fenus*) has a very long, slender abdomen, and the prothorax produced into a thin neck. *Fenus jaculator* is a not uncommon species found haunting the burrows of Crabronidæ, upon which it is probably parasitic. The American genus *Peleciscus*, which has been placed with these forms, although its abdomen is attached in the ordinary position, is remarkable for the very disproportionate length and slenderness of the abdomen in the females. *P. polycerator*, which inhabits both North and South America, attains a length of two inches, five-sixths of which consist of abdomen.

In the group of typical Ichneumonidæ, we have already referred to the genera *Ophion* and *Paniscus*, and their peculiar habits in the larva state. Many species of these, and allied genera, in which the abdomen is compressed, and the ovipositor short, are to be met with in Britain. In the genus *Ichneumon* proper, and many others allied to it, the ovipositor is also short, but the abdomen is either depressed or convex above. *Cryptus* has a nearly ovate abdomen and a projecting ovipositor; whilst in *Pimpla* and a number of other allied genera we find a long ovipositor for attacking concealed larvæ. A species of *Pimpla* (*P. manifestator*) is figured on p. I. It is a handsome black insect with red legs. The body measures thirteen lines, and the ovipositor seventeen lines in length, so that the whole insect is two inches and a half long. Many exotic species are larger, and have still longer ovipositors. In these insects the sheaths of the ovipositor serve as guides for the instrument itself when penetrating into hard bodies.

A large group, chiefly consisting of small species, is that of the Braconides, which differ from the typical Ichneumons in having the first submarginal cell more or less separated from the discoidal cell, and only one recurrent nervure, instead of two. Some of them have the ovipositor projecting; in others it is concealed. The abdomen is generally more or less ovate. The typical genus *Bracon* includes an immense number of species, and these are among the largest of the group. One of the best-known species is the little *Microgaster glomeratus*, which is parasitic upon the caterpillars of the common White Butterflies. The larvæ burst forth from the body of the caterpillar when it is ready to change, and form round its empty skin a little heap of yellowish cocoons. *Aphidius* and some nearly allied genera include minute species which are parasitic upon Aphides.



PANISCUS VIRGATUS (A), WITH YOUNG (B) AND OLD (C) LARVÆ. a, EGG-SHELL.

FAMILY PROCTOTRUPIDÆ.

A vast multitude of small parasites form this family, distinguished from the preceding by the structure of the fore wings, which have a distinct stigma on the anterior margin, but no complete cells, the veins being generally reduced to a few hardly perceptible longitudinal ones. In a great many species the wings are altogether wanting. The antennæ vary in structure, being either straight or bent, and they usually consist of fourteen or fifteen joints, but sometimes only of eight. The eyes

are not notched, the ocelli are indistinct, the prothorax is produced on each side as far as the insertion of the fore wings, and the abdomen consists of from five to seven rings, with the ovipositor issuing from its extremity. The hinder thighs are generally not thickened.



TELES LEUIUSCULUS,
MAGNIFIED.

The great majority of the species of this family are minute black insects, with opaque, hairy, whitish wings, and often, notwithstanding their minuteness, of exceedingly elegant form. Like the Ichneumonidae, they are parasitic in their habits, the females depositing their eggs in the eggs and larvæ of other insects, and attacking especially the larvæ of the Tipulidae, Aphides, Gall Flies, and Lepidoptera. The species are spread over the whole earth, and their number is incalculable in the present state of our knowledge. It may be observed, however, that over 150 genera have been established for the German forms alone. The larvæ, when full fed, spin a little cocoon for their protection during the pupa stage. As an example of this family we figure a small species (*Teles leuiusculus*), which deposits its eggs in those of certain Lepidoptera. It is a minute

shining black insect, with brownish legs. The species of the genus *Mymar* have slender wings, terminating in a broad expansion like a battledore. The expanded part is fringed with long hairs.

FAMILY CHALCIDIDÆ.

This is another large family of parasites distinguished from the preceding by several characters. The antennæ are always short and kneed, and consist of from six to fourteen joints; the fore wings have a costal vein, but scarcely any indication of others; the prothorax is not produced at the sides to the base of the wings; the hinder thighs are thickened, so that the hind legs are fitted for jumping; and the ovipositor, which may be either long or short, issues from the ventral surface of the abdomen at some distance from its apex. The abdomen consists of six segments in the females and of seven in the males. The species are excessively numerous, as may be judged from the fact that in England alone some 1,200 species have been recorded.

These insects, which are nearly all of minute size, species of half an inch long being giants among them, are parasites in other insects of the most various orders, and attack them in all stages of their existence, from the egg to the pupa. In all their habits they resemble the smaller Ichneumonidae, but among them we find the great majority of the species which are parasitic upon the parasites of other insects. They generally have the abdomen more or less compressed, and their surface usually shows metallic colours, but this is subject to exceptions, especially among some of the larger species. Thus the South European *Leucospis dorsigera*, which is parasitic in the nests of Bees, and measures four or five lines in length, is black, with bands on the prothorax and scutellum, three bands on the abdomen, the shaft of the antennæ and the legs yellow; and *Chalcis sispes*, a generally distributed European species, measuring one-third of an inch, is black, with more or less of the legs red. This last insect has been bred from a larva of *Stratiomys*. In *Eulophus pertinicornis*, a minute brassy-black species, a twelfth of an inch long, which is abundant upon oak trees, the antennæ consist of only three joints in the female, while the male has nine joints, three of which (the third to the fifth) bear each a long branch. The species of the genera *Blastophaga* and *Sycophaga*, which are common in the South of Europe, frequent the figs, and assist in the impregnation of the female flowers of those curious trees. Many of the species with elongated ovipositors are parasitic upon the larvæ of Gall Flies. The one figured infests the curious shaggy galls (Bedegnar's) of the briar.



CALLIMOME BEDEGUARIS.

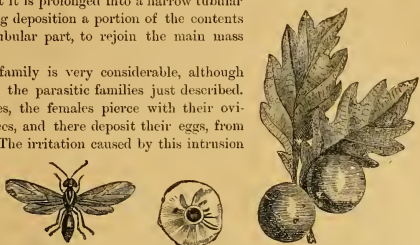
FAMILY CYNIPIDÆ, OR GALL FLIES.

In this last family of the Petiolated Hymenoptera, which is referred to the Entomophagous tribe from its structural characters, we find exceedingly few insect-eating species, by far the greater number feeding upon peculiar morbid excrescences of plants, known as galls, the growth of which is caused apparently by the puncture of the parent insect, and the presence of the egg or larva within the tissues. Thus, while they distinctly hold to the Entomophaga by their structure, they seem in their habits to lead towards the plant-eating forms constituting the following tribe.

The Cynipide are characterised by their unbent antennæ, which are usually thread-like, and composed of from thirteen to sixteen joints, the number being frequently greater in the males than in the females. The wings show no submarginal cells, except the apical one, and sometimes a very small one just within the stigma, at the apex of the discoidal cell. The abdomen, which is usually short, is strongly compressed, and only the first, or first and second segments, are greatly developed, the remainder being retracted within these, so that only their edges project. These fully-developed segments are much longer at the back than towards the ventral surface, so that the posterior margins of the segments, and that of the abdomen, become very oblique, especially in the female, and thus the ovipositor comes to issue from near the middle of the lower surface of the abdomen. Its arrangement is very peculiar. The last visible segment is produced within the others nearly to the base of the abdomen, where it has articulated to it a small triangular chitinous plate, to which the sheath of the ovipositor is also movably articulated. This sheath, as in the other Entomophaga, consists of two flattened joints on each side of the ovipositor, and the apical joints project from the abdomen, and, passing up along its posterior margin, produce the appearance of a sort of cleft. Within this the ovipositor lies, so that its point is directed upwards. By the action of muscles upon these parts, the ovipositor, which, in repose, is bent more or less in a spiral form, is pushed out from between the side-pieces forming the sheath when it is being employed in egg-laying. It consists, as in the Ichneumons, &c., of a principal superior piece, and two smaller pieces below, the whole arranged so as to form a triangular tube, for the passage of the egg. The latter is remarkable in its structure. It is considerably too large to pass easily through the narrow tube which has to convey it to its destination, but it is prolonged into a narrow tubular part capable of extension, and during deposition a portion of the contents of the egg is forced up into this tubular part, to rejoin the main mass when the process is completed.

The number of species in this family is very considerable, although in this respect it is far inferior to the parasitic families just described. Of the great majority of the species, the females pierce with their ovipositor the tissues of plants and trees, and there deposit their eggs, from which the larvæ are soon hatched. The irritation caused by this intrusion of a foreign body into the tissues would seem to give rise to a morbid state of the part affected, manifested by the production of an excrescence, which varies in size, form, and structure, according to the species of the Gall Fly producing it. The insects are generally confined to one species of plant, and to a particular part of it. The larvæ feed in the interior of the galls, sometimes singly, sometimes several in the same gall, but in the latter case each larva occupies a separate cavity. When full grown, the larvæ either undergo their change to the pupa state within the gall, or eat their way out, and, dropping to the ground, bury themselves under the surface, and there pass through their transformations.

The galls produced by different species differ greatly in form and structure. Some of them are round and smooth like fruits, such as the cherry galls of the oak leaves, produced by the puncture of *Cynips quercus-folii*; others show processes, or excrescences, of various kinds, such as may be seen in the well-known ink gall, the gall-nut of commerce, which is formed upon the twigs of a peculiar species growing in the Levant (*Quercus infectoria*), in consequence of the attacks of a rather large species, the *Cynips tinctoria*. This same oak also produces the so-called Dead Sea apples, which have been often celebrated poetically. They are as large and round as a good-sized apple, and each of them contains a single larva of a species described as *Cynips insana*. The most singular of all these galls is perhaps the Bedeguar, which is formed on the stems of wild roses by the puncture of a small species (*Rhodites rosea*). It is of considerable size, contains numerous larvæ, each in a separate chamber, and has its whole surface covered with compound bristles, like those on the calyx of a moss-rose, so that it closely resembles a ball of moss stuck on the stem or



GALL FLY. INTERIOR OF GALL. OAK-GALL PRODUCED BY CYNIPS.

branches of the rose-bush. The well-known oak-apples, which many people still wear on King Charles's Day, are another form of galls. They are produced on the twigs of oaks by the puncture of *Teras terminalis*. A very curious form of gall, which would generally be taken rather for a parasitic fungus than a gall, is to be found upon oak leaves in every wood. This is a little flat round disc attached to the surface of the leaf by a very small portion of its lower surface. Such galls are produced by two or three species of *Neuroterus*, which may be easily bred from them, if the leaves are collected in the autumn. *Biorhiza aptera*, a wingless species, lives on the roots of the oak.

Singularly enough, we have in this family once more to record cuckoo-like habits, many species of Gall Flies depositing their eggs in the galls produced by other species. The larvæ hatched from these eggs feed upon the substance of the gall, and in the end devour the rightful possessor. These parasites belong to the genus *Synergus*, a common species of which (*S. vulgaris*), black, with the mouth, antennæ, and legs red, breeds in the galls of *Cynips quercus-folii*.

The truly parasitic species form several distinct genera. *Ibalia cinctellata*, a large species, measuring half an inch long, black, with a red, knife-shaped abdomen, is parasitic upon the larvæ of wood-boring Beetles, or, according to some writers, upon that of the Tailed Wasp (*Sirex*). The species of *Figites* live upon the larvæ of Flies, and those of *Allothia* upon Aphides. None of them appear to attack insects belonging to their own family, but the true Gall Flies by no means have an immunity from parasites. Many Ichneumonidæ, and especially Chalcididæ, pierce the substance of the galls with their long ovipositors, and place their eggs in the contained larvæ. Thus *Callinome bedeguaris* (p. 4) haunts the Bedeguar galls, and another species of the same genus even makes its way underground to place its progeny in the root-galls of *Biorhiza*.

A remarkable circumstance connected with the insects of this family is that of a great number of the supposed species, especially those of the genus *Cynips*, only the females are known, the most pertinacious investigation having failed to reveal any males. Hence entomologists, headed by Mr. Siebold, long since came to the conclusion that as the unimpregnated females undoubtedly produce galls, we have here to do with a case of parthenogenesis. Recent researches have shown that in some cases, at any rate, what has been called an "alternation of generations" takes place; that is to say, that the parthenogenetic females are the offspring of male and female insects, so different from them in character as to be placed in different genera.

TRIBE III.—PHYTOPHAGA.

FAMILY UROCIDÆ, OR TAILED WASPS.

The remainder of the Hymenoptera, forming two families, are, as already stated, confined to a vegetable diet in all stages of their existence. The perfect insects are recognisable at once by their sessile abdomen, and the larvæ are more or less caterpillar-like, possessing six legs, and generally a number of pro-legs, and having a hinder opening to the intestinal canal.

The two families may be distinguished by various characters, but especially by the structure of the ovipositor. In the present family this organ generally projects considerably from the apex of the abdomen, and consists of essentially the same parts as in the preceding families, that is to say, two lateral plates, and a central, more or less serrated style, grooved along its lower surface. The antennæ are filiform, and consist of from eleven to twenty-four joints; the eyes and ocelli are well developed; the abdomen is elongated, usually nearly cylindrical, and composed of nine segments, with the dorsal plate of the first segment divided; and the anterior tibiæ have only a single spine at the apex. The larvæ resemble the grubs of Beetles rather than Caterpillars; they have six thoracic legs, which are often rudimentary, and generally no trace of pro-legs.

These insects present certain remarkable peculiarities of structure, such as the division of the dorsal plate of the first segment of the abdomen already alluded to, the purpose of which is at present unknown; the exceedingly free articulation of the neck-like prosternum with the pronotum, which gives the head great freedom of motion; the movable junction of the meso- and metathorax, which exists in this and the next family, and is a very exceptional character in the class of insects; and the presence of two transverse openings on the metanotum, the so-called "false stigmata," the function of which is unknown.

The family is not an extensive one, and its species occur chiefly in Europe and North America,

in both of which regions the typical genus *Sirex* is represented by large species. The best known European species, which is common in some parts of Britain, is the great Tailed Wasp (*Sirex gigas*, figured on p. 353, Vol. V.), a formidable-looking insect, of which the female often measures nearly an inch and a half in length. The general tint is black, with the antennæ, the sides of the head behind, and the tibiae and tarsi reddish-yellow, and the base and apex of the abdomen yellow. In the male the abdomen is reddish, spotted with black at the sides and apex. The maxillary palpi in this and other species of the genus are rudimentary. The general wasp-like aspect of this insect is sufficiently recognisable in our figure to explain the popular denomination that has been applied to it; indeed, many people mistake it for a Hornet, which they know to be a large Wasp, the long ovipositor of course being regarded as a peculiarly formidable sting. This insect lives in pine and fir woods, and the female deposits her eggs in the woody parts of the trees, into which she bores to a depth of over half an inch by means of her auger-like ovipositor. The larvæ hatched from these eggs bore deeper into the wood, forming tortuous passages, which gradually become wider as the larvæ increase in size, until they may have a diameter of a sixth of an inch or more. The larvæ themselves are fleshy grubs, with a horny head, and six very short thoracic legs. Of abdominal pro-legs there are no traces. The space left behind by the larva is filled up with a mixture of wood-dust and excrement. The question is not quite settled whether the development of the larva is completed within a single year, but this seems to be the most probable supposition; but as this period of its existence draws towards a close it prepares a somewhat wider chamber for the pupa, and, according to some entomologists (Ratzeburg, &c.), also makes a passage from this chamber to close under the surface of the stem, in order to facilitate the escape of the perfect insect. The latter comes forth in the summer months, and does not appear to enjoy a very long life. Both *Sirex gigas* and a rather smaller species (*S. juvenis*), the latter of a general steel-blue colour, which follow the same mode of life, vary greatly in abundance in different years. Occasionally, when the timber into which the larvæ have bored has been worked up into furniture, or employed in the woodwork of houses, the perfect insects will in due time emerge, sometimes in such numbers as to cause no small alarm to the human inhabitants. In flying, they produce a loud humming, much like that of the Hornet.

The curious little genus *Xiphydria* consists of a few species which have short antennæ, a round head supported upon a singularly long neck, five-jointed maxillary palpi, and an ovipositor shorter than in *Sirex*, although of the same general conformation. The commonest species is *Xiphydria camelus*, a black insect with white spots on the top of the head and along the sides of the abdomen, and with red legs; it is rather more than half an inch in length. This and the other species of the genus bore as larvæ in the wood of various trees (beeches, oaks, poplars, willows, &c). This genus in some respects leads towards the next family, and this is still more the case with another genus (*Cephus*), one species of which (*C. pygmaeus*) attacks different kinds of grain-plants, the female boring into the green haulm at one of the uppermost knots, and depositing an egg there. The larva hatched from this egg is almost footless, but it is able to make its way about in the narrow passage of the interior of the haulm, the inner layers of which constitute its food. The presence of this insect may be recognised in the field by the condition of the ears of corn; those of the stalks infested are light, and stand upright, while their healthy neighbours are heavy and bent down. When full grown, about harvest, the larva makes its way to the lowest part of the straw, and there encloses itself in a silken cocoon, in which it passes the winter, only passing to the pupa state a little before the emergence of the imago, which takes place about May.

FAMILY TENTHREDINIDÆ.

A much more extensive family than the preceding is that of the Tenthredinidæ, or Saw Flies, the latter name referring to the peculiar form of their ovipositor. Instead of being a piercing or boring instrument, as in all the preceding families, consisting of an upper channelled piece and two slender pieces closing the channel below, and thus completing the egg-canal, the ovipositor in the Saw Flies is a saw-like blade occupying the apical cleft of the abdomen, and composed of two lateral pieces only. What the precise constitution of this ovipositor may be is rather doubtful, but the two lateral serrated pieces would seem to represent the two inferior bristles of the other ovipositors of Hymenoptera, the unpaired median piece being undeveloped. The antennæ are usually short, frequently more or less

thickened at the apex, sometimes pectinated in the males, and composed in different genera of from three to thirty joints; the ligula is broad, and divided by deep notches into three parts; the maxillary palpi have six joints; the prothorax is produced at the sides to the origin of the fore wings; and the anterior tibiae have two spurs at the apex.

In their general habits these insects present a considerable uniformity. The females, by means of their saw-like ovipositors, cut slits in the leaves or tender growing shoots of trees and plants; the two plates of the saw are then separated a little, so as to widen the aperture already made, and then an egg passes down to its destination between them. The irritation produced by this process, assisted, according to some entomologists, by a peculiar secretion which accompanies the egg, causes a flow of sap to the wound, and the egg by contact with this quickly becomes considerably enlarged. The larvæ hatched from these eggs are generally very like the caterpillars of Butterflies and Moths in structure and appearance; they all possess three pairs of thoracic legs, and the great majority have, in addition, from six to eight pairs of abdominal pro-legs. These, however, differ from the corresponding organs in the larvæ of the Lepidoptera, by being destitute of the peculiar circlet of generally hooked bristles which the latter possess. The larvæ of the Saw Flies also have only a single simple eye on each side of the head. When full grown the larvæ spin a cocoon, which is sometimes parchment-like in its texture, sometimes lattice-like, and occasionally exhibits a combination of the two characters. These cocoons are either attached to the leaves and twigs of the plants and trees on which the larvæ have lived, or placed underground, but in either case the larva remains unchanged within its cocoon until the time for the emergence of the perfect insect approaches, when it undergoes the change to the pupæ state, and from this the imago is speedily produced. The number of known species of the family is estimated at over a thousand, a very considerable proportion of which live in Europe. Many of them are inhabitants of Britain.

The species of the genus *Lyda* have long bristle-shaped antennæ of numerous joints, a broad head, a flat abdomen, and three spines at the apex of the second and third pairs of tibiae. Two species (*L. pratensis*), a black insect with yellow markings on the head and thorax, and the abdomen margined with rusty red, and *L. campestris*, which is blue-black, with the middle of the abdomen reddish, and the antennæ, scutellum, tibiae, tarsi, and wings yellow, both about half an inch long, live on pines and firs, the larvæ feeding in company under a sort of web which they spin; another rather smaller species (*Lyda betulae*), which is reddish-yellow, with the thorax and the base and apex of the abdomen blue-black, feeds on the birch, and is very generally distributed. *Lophyrus pini* is a very common species on coniferous trees. The sexes differ in colour, the male being black with yellow legs, and the female yellow, with the head, three spots on the thorax, and the middle of the abdomen black; the antennæ in the female are serrated, in the male pectinated on both sides. The insect is about a third of an inch long, and, like the species of *Lyda* above mentioned, sometimes does considerable damage. *Nematus ventricosus*, a small reddish-yellow species, about a quarter of an inch long, with the breast and three spots on the back of the thorax blackish, haunts gooseberry and currant bushes, producing two broods in the year, and sometimes almost stripping the bushes of their leaves. *Emphytus grossulariæ* is another enemy of



LOPHYRUS PINI.

the gooseberry. *Athalia spinarum* is a species of a reddish-yellow colour, with the head and the sides of the posterior part of the thorax black. It measures about a quarter of an inch in length. The larva feeds on the leaves of the turnip and other cruciferous plants, to which it frequently does great mischief. The species of *Hylotoma*, one of which (*H. rosarum*) attacks roses, have only three joints in the antennæ, the last joint being longer than the others; in those of the genus *Cimex*, which are among the largest in the family, the antennæ have seven or eight joints and terminate in a good-sized club. *Penthredo athiops*, a small black species, deposits its eggs upon fruit-trees, showing a preference for cherry-trees. Its larva is black, and often occurs in such abundance as to damage the trees. The larvæ of certain small species mine the leaves of the plants on which they feed; while the irritation caused by the presence of others produces small excrescences or galls within which they live. A common example of this last habit is the little *Nematus saliceti*, the larvæ of which reside in small protuberances of the leaves of several species of willows.

ORDER NEUROPTERA.

CHAPTER VIII.

THE FLAT-WINGED NEUROPTERA AND THE CADDIS-FLIES.

NEUROPTERA—Characters—Habits—Classification—PLANIPENNIA—MEGALOPTERA—Characters—THE MYRMELEONTIDÆ, OR ANT-LIONS—Habits—Capture of their Prey—THE HEMEROBIDÆ—The Golden-eyed Fly—The Genus *Neuroptera*—THE MANTISPIDÆ—THE SIALIDÆ—The *Sialis lutaria*—The Snake-flies, or Camel-flies—THE PANORPIDÆ—THE SCORPION-FLY—Habits—Genus *Bittacus*—Genus *Boreus*—TRICHOPTERA—Caddis-flies—Difficulty of Assigning their Proper position—McLachlan's Classification—Characters—Distribution—Metamorphoses—The Phryganeidæ—The Limnophilidæ—The Sericostomidæ—The Leptoceridæ—The Hydropsychidæ—The Rhyacophilidæ—The Hydroptilidæ.

THE order Neuroptera of the older entomologists included all the insects which possess four membranous wings more or less elaborately veined, but not after the Hymenopterous type, the veins running straight through the wing, with a larger or smaller number of branches, and either simply parallel or united by more or less numerous cross veins. The peculiar arrangement of cells seen in the fore wings of the Hymenoptera (see figure on p. 354, Vol. V.) never occurs in these insects. Between the insects thus brought together by the possession of wings more or less similar in character there is, however, a very important difference. Some of them, and the larger

number, only pass through an imperfect metamorphosis, being active and voracious in all stages of their existence; while the rest have a complete metamorphosis, the larva being quite different in structure from the perfect insect, and the pupa quiescent.

The latter constitute the order Neuroptera of modern authors, and they may be defined as insects with a perfect metamorphosis, a mandibulate mouth, a free



COMMON ANT-LION.

prothorax, and four more or less veined membranous wings. It must be confessed, however, that in this definition the character of the metamorphosis is the only one separating them from the other membranous-winged insects which were formerly associated with them, but are now commonly referred to the great order Orthoptera; and further, that from circumstances, especially the remarkable differences presented by the members of both groups among themselves, it is exceedingly difficult to frame a broad definition, applicable to the perfect insects alone, which will serve for the discrimination of the two series.

There is one character, however, which almost universally holds good, and this is derived from the structure of the ligula. Throughout the more highly organised Orthoptera the ligula is, almost without exception, divided or cleft in front, either into two or four lobes, and the indications of division may even continue down into the basal part of the labium, showing very clearly the original construction of the whole labium out of a pair of organs similar to the maxillæ. In the true

Neuroptera, although the ligula is occasionally cleft in front, the general rule is that the parts of the labium are united in the middle line so closely as entirely to conceal the original constitution of the organ of two lateral halves, so that the labium really approaches that of the Beetles more nearly than that of the Orthoptera.

The Neuroptera may be characterised generally as rather soft-skinned insects, with a head of small or moderate size, closely applied to the thorax, and having a pair of well-developed compound eyes, and a pair of usually many-jointed, bristle-shaped, or necklace-like antennae, which are sometimes clubbed at the end. The ocelli are frequently wanting. The parts of the mouth are variable in their development; their characters will be described under the two principal groups into which we divide the order. The prothorax is always free, sometimes ring-like, sometimes considerably developed; the veins of the wings may be either simple or united by cross-veins; the tarsi are usually of five joints; and the abdomen consists of eight or nine segments. In some cases there are tail-like appendages at the extremity of the abdomen, but these, when present, are not jointed organs such as occur in the Orthoptera.

The Neuroptera have generally a short intestine, usually provided with a sucking stomach, and in many with a globular proventriculus. The Malpighian vessels are long, and from six to eight in number. The females of certain forms are provided with special glands connected with the oviduct, the secretion from which serves to form an envelope for the eggs, or a long stalk upon which they are supported when laid. The larvæ are provided with the usual six thoracic legs, and the abdomen in many species bears peculiar appendages which assist the insect in its movements. Many species, in fact the whole of one of the two great divisions, are aquatic in the larval state. The pupæ is sometimes free, sometimes included in a cocoon spun by the larva. In character it resembles the pupæ of the Coleoptera and Hymenoptera, having all the limbs and other appendages enclosed in separate sheaths, and free; but the pupæ of the Neuroptera usually acquire the power of movement just before the emergence of the perfect insect, and this enables them to get into a suitable position for this final change, which is especially important in the case of the aquatic species.

In their habits the Neuroptera present no special peculiarities. They are generally not particularly active in the perfect state; some of them fly in the day time, while others are chiefly on the wing in the evening twilight. Some are carnivorous in their habits, whilst others either feed on the nectar of flowers or abstain altogether from food. The larvæ of one of the two principal groups are carnivorous, those of the other chiefly herbivorous, although animal food does not come amiss to them. The order is but a small one, the number of known species from all parts of the world probably not greatly exceeding 1,500.

The geological distribution of the Neuroptera is very difficult to ascertain, owing to the similarity of the wings of these insects, the chief parts preserved, with those of the Orthopterous Pseudoneuroptera, which, as already stated, were formerly included with them in the same order. It would appear, however, that the order is not of ancient date. The Palæozoic types, which have been described as Neuroptera, seem all to be either Pseudoneuroptera or most nearly allied to that tribe. In the Trias forms which appear to be related to the existing North American genus *Chauliodes* have been met with, and in the Lias and Oolites a few species of different families occur. In Tertiary deposits they are more plentiful, but the number of recorded fossil species is not great.

The Neuroptera as here defined are divided into two principal groups (sub-orders). These are:—

I. *PLANIPENNIA*, having the fore and hind wings similar, usually both in form and structure, the hind wings never broader than the others and folded; the organs of the mouth fully developed and generally distinct, the mandibles being horny biting organs, the maxillæ furnished with two separate lobes, and five- or six-jointed palpi, and the labium generally distinct, with three-jointed palpi; the prothorax generally well developed, and the other two segments nearly equal. Larvæ rarely aquatic.

II. *TRICHOPTERA*, with the wings clothed with hairs or hair-like scales, dissimilar, the hinder ones generally wider than the others and folded, the mandibles reduced to mere membranous rudiments, and the maxillæ and labium united into one mass, the former having palpi of from two to five joints, and the latter either three-jointed palpi or none at all, the prothorax ring-like, and the mesothorax much larger than the metathorax. Larvæ aquatic.

SUB-ORDER I.—PLANIPENNIA.

FAMILY MEGALOPTERA.

This family, which includes the most typical forms of the Planipennia, or Flat-winged Neuroptera, may be at once distinguished by the position of the head, which is set on perpendicularly in front of the thorax, that is, with the mouth directed downwards, but not produced into a sort of beak. The upper surface of the head usually has no ocelli. The parts of the mouth are all separate, and the ligula is not cleft. The abdomen is long and slender.

Although the perfect insects of this family exhibit some divergence in external characters, their larvæ present a close resemblance in structure. They are shorter and flatter in form than the parent insects, and furnished with six well-developed legs. Their food consists of other insects, in the capture of which some of them exhibit remarkable cunning and contrivance, and their instruments for taking nourishment show a very curious modification of the organs of the mouth. The mouth is in fact closed up, the labium, which bears a pair of jointed palpi, being firmly soldered to the under surface of the head; above it is a pair of long, curved, and sharp forceps, formed by the mandibles, which are deeply grooved along their lower surface, and the maxillæ, which are slender, and exactly close the groove in the mandibles from beneath. In this way the two pairs of jaws become converted into a pair of tubular, sickle-shaped forceps, and when the points of these are plunged into the body of another insect, the juices of the latter can readily pass into the two channels, which open at the base directly into the œsophagus. The pupa is enclosed in a cocoon, the material for which is derived from a gland situated in the terminal part of the intestine.

The MYRMELEONTIDÆ, or ANT-LIONS, are among the most interesting forms of this great family. They may be distinguished at once by having their antennæ clubbed at the tip. The larvæ have a rather large head, and the inner edge of the mandibles toothed.

The common ANT-LION (*Myrmoleon europæus*, see figure on p. 9), which is abundant in sandy places in the South of Europe, is a slender and elegant creature, with large finely reticulated wings, not unlike a very delicate form of Dragon-fly. It measures rather more than an inch in length, and is of a blackish colour, with a yellowish head spotted with black, and transparent wings with scattered brownish spots. Its larva, to which the name of Ant-lion properly belongs, is of a stout form and a greyish-yellow colour, covered with warty processes and with hairs. It bears seven simple eyes and a short antenna on each side of the head; its tarsi consist of a single joint, terminated by a pair of strong claws; and it moves in a jerky manner and always backwards. Its food consists of Ants and other small insects, which it captures by a singularly ingenious arrangement, namely, a funnel-shaped pitfall in the sand, at the bottom of which it lies waiting until some unlucky victim, venturing over the margin of the pit, gets upon the treacherous slope of sand, which affords no secure foothold. When the descent of grains of sand reveals the presence of a prey to the Ant-lion patiently waiting below, he throws up a shower of sand which helps the victim in its descent. The labour undergone by the Ant-lion in the construction of his funnel-shaped pitfall is very considerable. He commences by making a circular excavation which marks out the size of the pit, and having completed this, proceeds most laboriously to dig out the space thus circumscribed to the required depth. In doing this he works usually in a spiral direction, always going backwards. The sand is placed by the action of the legs upon the surface of the shovel-like head, and then by a jerk thrown quite beyond the boundary of the pit, and the larva is so active in its operations than when at work it produces a continuous shower of sand. On completing its dwelling it buries itself in the sand at the bottom, frequently, however, allowing its formidable jaws to project a little. The larva is supposed to live for two years. The perfect insect is rather sluggish.

A second species of *Myrmoleon*, with similar habits (*M. formicarius*), is abundant in

Europe; and the larvæ of some other species make no funnel, but simply conceal themselves beneath the sand until their prey comes within reach. There are many exotic species, and some of them, especially in warm climates, reach more than double the dimensions of the European forms, and show a much more vivid colouration. This is the case also with the species of the genus *Palpares*, which have shorter and stouter antennæ than the preceding, and the first four joints of the tarsi very short. *Palpares libelluloides*, which inhabits the South of Europe, is about two inches long and four inches across the wings. It is of a yellowish colour, with black streaks; and the wings are clouded with yellow and adorned with large and small brown spots. The *Ascalaphi* (see figure on p. 13), which much resemble Moths

in general form, have the antennæ long and slender, and terminated by very distinct clubs like those of some Butterflies. These insects also are adorned with bright and contrasted colours, which adds to their resemblance to Lepidoptera.

The HEMEROBIDE have the antennæ either thread-like or necklace-like, and not clubbed; and their larvæ are slenderer in form and have a smaller head than the Ant-lions. These insects, like the preceding, are of slender and delicate forms, and have very finely reticulated wings, but in general the abdomen is less elongated. Some species are exceedingly abundant and well known in England, such as the beautiful GOLDEN-EYED FLY (*Chrysopa vulgaris*), which we may take as an example of the group. This is a most delicate green insect, with a body less than half an inch long, which may be seen almost everywhere in warm summer evenings flying slowly about upon four wings having the appearance of green gauze, and consisting of a transparent membrane traversed by a most delicate network of green veins. The prominent hemispherical eyes are of a beautiful golden colour. It emits an exceedingly disagreeable odour. Many other species of this and the nearly allied genus *Hemerobius* occur abundantly in Britain, and all have nearly the same habits. The eggs, which are little round or oval bodies, like small seed-pearls, are deposited by



PALPARES LIBELLULOIDES.

the females in groups upon the leaves of plants and trees, and in *Chrysopa* each egg is supported upon a long and slender stalk, giving it something of the aspect of a small fungus, for which, indeed, these eggs have been mistaken. The stalk is formed by the secretion from a peculiar gland connected with the oviduct. The female, on applying the extremity of her abdomen to the spot on which she purposes to deposit an egg, allows this glutinous material to adhere to the surface, and then raising the end of her abdomen, with the egg still retained within it, draws out the viscid secretion into a slender hair-like thread, upon the upper end of which the egg is borne when it quits the body of its parent. The general characters of the larvæ hatched from these eggs have already been described; they are distinguished from those of the

Ant-lions not only by their form, but by having no denticulations on the inner surface of the jaws. They devote themselves to the destruction of the Aphides which infest various trees and plants in such numbers, and are frequently so injurious to them, and it will easily be understood that a rapidly growing larva of about half an inch long will commit very considerable havoc among such feeble and sluggish creatures as the Plant-lice. In the hop-gardens these larvæ always abound, and one of the species has received the name of *Hemerobius humuli* from this circumstance. The cocoon is attached by the larva to a leaf, and under favourable circumstances the imago soon makes its appearance, so that there are several broods of these insects in the season. These insects

may be observed in mild weather until late in the autumn; and they pass the winter in the perfect state in some sheltered locality.

Several other genera belong to this group, but of these we will notice only the curious forms constituting the genus *Nemoptera*, in which the hind wings, instead of being similar and nearly equal to the fore wings, are very long, forming a sort of strap, of which the extremity is a little dilated, while the fore wings are very much broader than is usual in the family. These insects, which are exceedingly elegant, live in the warmer parts of the Old World, from Southern Europe to Australia. They fly

briskly in the hottest sunshine. Their appearance in flight is illustrated in the above figure of the European species (*Nemoptera coa*), which inhabits Turkey and the adjoining parts of Asia and Africa. The transformations are not exactly known, but the larva of *N. coa* is supposed to be a singular little creature described by M. Bertrand Roux under the name of *Necrophilus arenarius*, having an oval body, with an excessively long, slender neck, composed of the prothorax.

The MANTISPIDÆ, including the single genus *Mantispa*, which appear to be most nearly related to the Hemerobiidæ, and, indeed, are referred to that group by some writers, are distinguishable at the first glance by the structure of the fore legs. These are elongated and converted into raptorial organs, resembling those of the Mantidæ, Praying Insects, or Soothsayers, which we shall have to describe under the order Orthoptera, the coxæ being much lengthened, the femora freely articulated at their extremity, somewhat thickened, and spined or toothed beneath, while the tibiæ are attached to the extremity of the femora by a hinge joint, and with the tarsi shut against the lower surface of the thighs, like the blade of a clasp-knife. To add to the resemblance to the Mantidæ the



NEMOPTERA COA AND ASCALAPHUS LONGICORNIS.

prothorax is much elongated, and the head is rather broad, with prominent eyes. The species, which are of moderate size and not very numerous, are found in all the warmer parts of the world. A single species (*Mantispa pagana*) is common in Southern Europe.

FAMILY SIALIDÆ.

In this second family of the Planipennia the head is placed nearly horizontally in front of the thorax, so that the opening of the mouth is in its front part instead of beneath. The antennæ are



SIALIS LUTARIA.

bristle-shaped or thread-like; the ocelli are generally present; the ligula is membranous, cleft in the middle; the fore and hind wings are similar, except that the former have a more dilated anterior margin. The larvæ of all but one exceptional form live in water, and are furnished with branchial filaments on all the abdominal segments; the pupa is not enclosed in a cocoon.

The common British species (*Sialis lutaria*) is a blackish-brown insect rather more than half an inch long; it is well known as a bait to anglers, and may be found abundantly in the spring and early summer upon walls and palings in the neighbourhood of water, and upon the stems and leaves of grasses and other plants growing in the water or upon its brink. In repose the wings in these insects, as in the Hemerobiidæ, are laid together in the form of a roof on the back of the insect. They are sluggish and inactive and do not readily take to flight. The female deposits a great quantity of brown eggs, attaching them in a compact mass to the stems of rushes and other aquatic plants; the eggs form short cylinders which are attached by one end side by side with great regularity; and the opposite end is suddenly narrowed and terminated by a small slender point. The larva hatched from these eggs is elongated, with a large horny head and powerful mandibles;

the three segments of the thorax are also horny, but those of the abdomen are soft, and each furnished with a pair of articulated bristly filaments which serve as gills, and also assist the larva in swimming through the water, which it does with facility. The abdomen is terminated by a long bristly tail. When full grown the larva quits the water and burrows into the soil of the bank, where it forms a little cell and there undergoes its change to the pupa state. The pupa is not enclosed in a cocoon, and shows all the parts of the future insect, each enclosed in its separate sheath. It remains in this condition showing no signs of life, except a brisk twisting of its abdomen if disturbed, until the time comes for the emergence of the perfect insect, which takes place within the chamber.



LARVA AND PUPA OF SIALIS LUTARIA.

This insect and a few of its immediate allies have no ocelli; in the rest of the group three of those organs are present and often of considerable size. The species of *Corydalis* and *Chauliodes* (*Corydalis cernuus* is a well-known North American species) are distributed over the warmer parts of the world; the antennæ are more or less pectinated, especially in the males, and this sex is also further distinguished by the large size of the mandibles and the presence of a pair of forceps-like appendages at the apex of the abdomen. Their larvæ live in the water like those of *Sialis*.

The Snake-flies, or Camel-flies (*Rhaphidiæ*) form a small genus which is now generally referred to this family, but the position of which has given entomologists some trouble. They have a rather large head, with smallish eyes and usually three ocelli, which is attached to a greatly elongated prothorax by a thinnish neck, so that the head has considerable freedom of motion in a vertical direction. The insect usually carries its long prothorax a little elevated, and its head bent down, very much after the fashion of a snake with its head raised. The species are not numerous, and the greater part of those known are inhabitants of Europe, chiefly in the southern parts. Four species live in Britain. The larvæ reside under the bark of trees, where they feed upon minute insects; they have a large prothorax like the perfect insect, and are tolerably active, often wriggling about in a serpentine fashion. The pupa is not enclosed in a cocoon.

FAMILY PANORPIDÆ.

This family is a curious little group, characterised above all things by the perpendicularly placed and greatly elongated head, forming a regular beak, at the end of which the free organs of the mouth are seen, namely, a pair of small toothed mandibles, the lobes of the maxillæ and the maxillary and labial palpi. The maxillæ and labium are more or less united, forming the lower surface of the beak. The insects have longish, filiform antennæ, moderate, oval eyes, usually three ocelli, a ring-shaped prothorax, and generally four precisely similar wings, showing branched longitudinal veins, but very few cross veins. The legs are long, sometimes much elongated. The larvæ, so far as they are known, live in the earth, and are like caterpillars in their general form; they have a horny head, and three pairs of short, thoracic legs; their bodies consist of thirteen segments. The pupa resides in a little chamber underground; in its characters it resembles those of the other Neuroptera, and it has no cocoon.

The species of this family are not numerous, but they are pretty generally distributed over the face of the earth, those of the more typical genera, however, being chiefly inhabitants of the temperate parts of the northern hemisphere. They are predaceous in their habits, feeding upon smaller and weaker insects, which they seize in various ways. Of the typical genus

Panorpa, the best known species is the Scorpion-fly (*P. communis*), a common British insect, which may be met with almost everywhere about hedge banks. It is rather more than half an inch long, shining black, with the scutellum and legs yellow, the beak, and in the male the last three segments of the abdomen, reddish. The wings are transparent with dark brown spots, which are more or less confluent, and generally form three dark bands. The name of Scorpion-fly is given to this insect in



SCORPION-FLY, MALE AND FEMALE.

allusion to a peculiarity of the male. In both sexes the segments of the abdomen beyond the sixth become much more slender, and in the females all of them taper gradually towards the extremity, which bears a pair of small three-jointed styles. In the male the seventh and eighth segments are narrow, and generally carried more or less elevated, while the last joint is swelled into a sort of knob, which bears a pair of forceps. When the insect is alive, with this slender tail and its inflated termination raised above the general level of the body, the analogical resemblance to a Scorpion is unmistakable; the terminal swelling is, however, a far more innocent appendage than the Scorpion's sting, and is only a clasping organ which comes into use during the union of the sexes.

The common Scorpion-fly is active during the day, and may be found walking about upon the leaves of the herbage in hedge-bottoms and on small bushes, usually in damp situations. Its appearance as it stands upon a leaf is peculiarly brisk and wide awake, and its movements are also lively. It usually pounces upon its prey by short quick flights, and from some observations which have been recorded, it would appear to be a bold marauder, sometimes attacking insects much larger than itself, and boring into them with its long beak. The female, about four days after pairing, deposits, by means of the extensible terminal joints of her abdomen, a mass of little white eggs in a small cavity in damp earth. In a

little more than a week the larvæ are hatched, and they feed upon decomposing vegetable matters which they meet with underground. They have, besides the three pairs of horny thoracic feet, eight pairs of fleshy pro-legs on the following abdominal segments, and from the last segment the larvæ can protrude four short tubes from which a white fluid exudes. The larva is full grown in about a month, and then goes deeper in the earth, where it forms a small chamber, and remains there for a time awaiting its change to the pupa state; and the pupa stays in the same cavity for about a fortnight, and then makes its way to the surface in order to give birth to the imago. The average time required for this development is about nine weeks, and there are thus two broods in the course of the year, the progeny of the second brood surviving the ensuing winter either in the larva or the pupa state.

Another curious genus of this family is *Bittacus*, the species of which have very long bodies and very long legs, and thus closely resemble the common two-winged flies vulgarly known as "Daddy Long-legs" (*Tipula*), in everything but their possession of four wings. The tibiae of these insects have very long spurs at their apex, and the tarsi have only a single claw; the beak is shorter and the wings longer than in *Panorpa*. The genus includes several species which are chiefly inhabitants of warm climates. *Bittacus tipularius* is the most abundant of the two species found in Europe, and it is confined to the southern parts of the Continent. This insect is about an inch long to the tips of the closed wings. It is of a reddish-yellow colour, with a great part of the thorax and the tips of the tibiae and the tarsi brownish. The wings are yellowish without any spots. It is a somewhat sluggish insect, flying slowly and waveringly in the twilight. The *Bittaci* are, nevertheless, as predaceous in their habits as their more active relatives, the Scorpion-flies; but instead of going in pursuit of their prey, they adopt the lazier method of hanging themselves up to a twig by their fore feet, and seizing with their other long legs any unfortunate flying insect that comes within reach. Curiously enough, the pairing of these insects takes place when they are suspended as above described, and, as a general rule, the pair are engaged in devouring some small insect which they hold between them with their disengaged feet. This remarkable habit is not altogether peculiar to the *Bittaci*, the females of several predaceous flies being always engaged in sucking some prey during the time of pairing, the reason being, no doubt in all cases, that if the male ventured to pay any attention to his partner while her mouth was disengaged he would himself fall a victim to his own temerity and her voracity.

Besides these amply-winged forms we have to refer to the Panorpidæ some very curious little creatures forming the genus *Boreus*, in which the wings are useless for flight, quite rudimentary in the females, longer and claw-like in the males. These insects have the beak long, the antennæ almost as long as the body, no ocelli, and two claws on the tarsi. The female has a projecting ovipositor. To make up for their want of wings these insects possess a considerable power of leaping; in fact, the common European species was described by one of the older entomologists as a cricket on this account. This common species, which occurs, although not abundantly, in Britain, is called *Boreus hiemalis*, both its names referring to its being peculiarly a northern and winter insect. It does not exceed a sixth of an inch in length, and is of a metallic green colour, with the beak, antennæ, legs,



BOREUS HIEMALIS, MALE.

rudimentary wings, and ovipositor, rusty red. From October to March is the season at which this curious little creature is most commonly met with. It is found on the ground among fallen leaves, or upon the snow, and is even met with on the ice of glaciers. The larva lives in moss, and buries itself in dry ground when about to change to the pupa state. Both larva and pupa much resemble those of the Scorpion-fly. Several other species are known, especially in North America, and all have the same habits.

SUB-ORDER II.—TRICHOPTERA.

The members of this group are the insects commonly known as *Caddis Flies*, and we have retained them as belonging to the Neuroptera, although some entomologists are inclined to rank them as a distinct order of insects. This, indeed, was done many years ago by Kirby, and he was

followed in this course by English writers generally (such as Leach, Westwood, and Stephens); and Mr. McLachlan, in his monograph of the European species of the group, also states that his tendency is to separate them from the other Neuroptera. Their relationship to the Saw-flies among the Hymenoptera has been exaggerated; but, on the other hand, their close affinity to the Lepidoptera, through some of the lower forms of that order, is unmistakable.

The systematic study of these insects is attended with very considerable difficulties, owing, to a great extent, to the obscurity and minuteness of the distinguishing marks to which it is necessary to have recourse. In general character, in the nature of the metamorphosis, and in the mode of life of the insects there is such an agreement as would seem to mark them as one family, and by most entomologists they are so treated. To divide them up into subordinate groups (families or sub-families) it is necessary to appeal to very minute distinctive features. Nevertheless, it will be of use to the reader to have a classification of these insects to refer to, and we therefore reproduce here, with some modifications, the table of families given by Mr. McLachlan in his admirable "Monographic Revision and Synopsis of the European Trichoptera," which has already been alluded to:—

DIVISION I.—INÆQUIPALPIA.

Maxillary palpi, differing in the number of joints in the two sexes: five-jointed in the females:—

- | | |
|---|----------------|
| A. Form of maxillary palpi similar in both sexes: those of the male not very pubescent:— | |
| 1. Maxillary palpi of the male four-jointed | PHYTOGANEIDÆ. |
| 2. Maxillary palpi of the male three-jointed | LIMNOPHILIDÆ. |
| B. Maxillary palpi of males two- or three-jointed, very different from those of the females, usually very pubescent | SERICOSTOMIDÆ. |

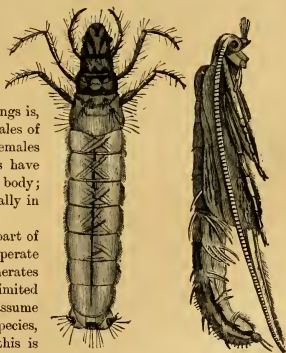
DIVISION II.—EQUIPALPIA.

Maxillary palpi, five-jointed, and usually similar in form, in the two sexes:—

- | | |
|---|----------------|
| A. Maxillary palpi, strongly hairy, usually ascending, the last joint long but simple; wings pubescent; antennæ long and slender | LEPTOCERIDÆ. |
| B. Palpi either rudimentary or long, more or less bent down, with the last joint whip-like, composed of numerous minute jointlets; antennæ variable | HYDROPSYCHIDÆ. |
| C. Palpi bent down, rarely hairy, last joint like the others | RHYACOPHILIDÆ. |
| D. Palpi simple in structure, very hairy; antennæ short and stout; insects minute, very pubescent and hairy | HYDROPTILIDÆ. |

The Trichoptera are for the most part moth-like insects, having a smallish head, with the mouth downwards, and usually three ocelli at the vertex; the antennæ are bristle-shaped, generally long, and the first joint is thicker than the rest and more or less elongated; the eyes are hemispherical; the wings differ in form, the hinder ones being wider, shorter, and more rounded than the anterior; in repose the wings wrap round the body, and, in consequence, the hind wings are folded. The number of transverse veins in the wings is always very small, and the surface of the wings is, with very few exceptions, clothed with hairs. In the males of a few species the hinder wings are rudimentary, and the females of *Enoicyla* are almost destitute of wings. The legs have large, conical coxæ, meeting in the middle line of the body; and the tibiæ are spurred at the apex, and also generally in the middle.

Species of this group are found in nearly every part of the earth, but they seem to be most abundant in temperate climates. Mr. McLachlan, in the work already cited, enumerates in all 474 species from the European region, which, as limited by him, includes certain parts of Western Asia. If we assume that these constitute about one-half of the known species, we may estimate the total at about 1,000. No doubt this is very far from the whole number of Trichoptera existing on the earth. They are insects which do not greatly attract the



LARVA AND NYMPH OF SPECIES OF THE GENUS LIMNOPHILUS, ENLARGED.

travelling collector, and judging from Dr. Fritz Müller's article on the dwellings of the Trichoptera of the neighbourhood of Santa Catharina, in Southern Brazil, we may fairly assume that when the Caddis-flies of tropical countries have been better studied, the present apparent preponderance of the species of temperate climates will at any rate be considerably diminished. The insects are found about water, generally resting upon the leaves of plants or upon the trunks of trees and palings. Some of them are tolerably active in the day-time, whilst others move about



THE METAMORPHOSIS OF THE CADDIS FLIES, *LIMNOPHILUS FLAVICORNIS*, L. LUNATT'S,
AND *L. RHOMBICUS*.

only in the evening and night. The females deposit their eggs upon plants growing in or close to the water, or upon stones similarly situated. The eggs are enclosed together in a gelatinous mass, formed by the secretion from a pair of large glands connected with the oviduct.

We have already noticed the resemblance of the perfect insects to Moths, and the larvæ also present a similarity to the caterpillars of many Lepidoptera. They are elongated, more or less cylindrical, soft-bodied creatures, having only the head, the segments of the thorax, or some of them, and the six thoracic legs horny; and the segments of the abdomen, from the second onward, are usually amply provided with branchial filaments, two or three of which spring from a point on each side of the segments on the dorsal or ventral surface. To protect this soft body the larva makes himself a little habitation, which is composed of the most various materials by different species. Fragments of wood and leaves, short lengths of reeds, and other hollow stems, small stones and grains of sand, little shells, often with their owners still living in them, and sometimes even the cases of other smaller Caddises are made use of; but each species usually employs the same materials, or, at any rate, the same class of materials in the construction of its dwellings. These materials, whatever they may be, are held together by means of silky threads produced by glands which have their opening in the labium of the larva. The cases are often at first tapering; but in most instances the larva prefers a cylindrical dwelling, and after a time removes the slender posterior end and uses the materials, along with others, to add to the length of the case at the wider end. The cases are open at both ends, and in some instances the larva appears to turn round in his

house. Some larvæ have fixed cases, others move freely about by protruding the head and first two thoracic segments from the mouth of the case, when they are able to walk upon the feet attached to those segments. Their hold of the interior of their dwelling is secured in part by the legs of the third pair, which are often much elongated, and in part by certain more or less hook-like appendages to the apex of the abdomen. The long hind legs are mainly instrumental in drawing the larva back within its case, which they can do very rapidly should any danger threaten, the Caddis-worms, as they are commonly called by anglers, being not unwelcome articles of food to fishes and other predaceous aquatic animals. We must add that the larvæ of different species live in all sorts of water, from the most stagnant pond to the mountain torrent, and that their food consists chiefly of aquatic plants, although occasionally they will not disdain animal food.

When full grown, the larva prepares for its change to the pupa state by shortening its case, and closing both apertures of its dwelling with silk and vegetable materials or small stones, but so that the water still has free access to the interior, the closure being sometimes effected by a circular grating of very ingenious construction. The case is also attached and often strengthened at this time. The change to the pupa then takes place within the case, and after a longer or shorter time the pupa breaks out of its dwelling and makes its way out of the water, in order to cast off its last covering, and give birth to the perfect insect.

The Phryganeidæ include the largest species of the order, although found only in northern regions. Thus *Neuronia phadenoides*, a north European species, which occurs in Northern Asia, but does not extend its range so far west as Britain, measures nearly an inch long in body, and has an expanse of wing of about two inches and a half. It is a black insect, with white wings, variegated with numerous black spots. One of the largest British species is the *Phryganea grandis*, which measures four-fifths of an inch in length, and over two inches in expanse of wing. It is an abundant insect, of a brown colour, with yellow rings on the antennæ, and the anterior wings ash-coloured, clouded with brown. The larvæ of this group inhabit quiet waters, ponds, lakes, &c. Their cases are cylindrical, and formed of vegetable materials, such as fragments of leaves, fibres, &c., usually arranged in a more or less spiral manner.

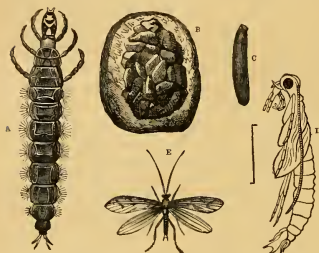
The Limnophilidæ are a very extensive group, many species of which occur in Britain. The larvæ live both in standing and running water, and some of them even in torrents. Their cases are very varied in structure. *Limnophilus rhombicus* (see figure on p. 18) forms a case of vegetable fragments, such as detached fibres, portions of grass, and bits of moss, which are arranged transversely, so that the outer surface presents a rough, bristling appearance. *L. flavicornis* (see figure on p. 18) uses a variety of materials in the construction of its case, such as fragments of wood, shells, and small stones, but entire shells, often with the living inhabitants, are the most common. Another species (*L. stigma*) employs small round pieces of the leaves of willows, which are laid one over the other, while *L. lunatus* (see figure on p. 18) makes a case of sand grains mixed with vegetable matter, and then attaches to the outside larger pieces of wood, and even long twigs, which may project beyond both ends of the case. This species lives in standing water. The larva of *L. politus* takes up its abode in a fragment of reed, which it bites to the right length, and then attaches long twigs to it at both ends, and that of *L. vittatus* makes a curved cylindrical tube of fine sand. The larvæ of the genus *Stenophylax* live in running water, and often in mountain torrents. Their cases are generally tubular, formed of fine sand, and temporarily attached to large stones, or the larvæ keep their cases free; and shelter themselves behind stones at the bottom of the water. *Thamastes dipterus*, a Siberian species, is remarkable for having the posterior wings quite rudimentary, and the maxillary palpi three-jointed in both sexes. The species of *Enoicyla* have the females nearly wingless, the wings being represented only by triangular scales. The larvæ live among moss at the roots of trees, and often at a great distance from water. They make a cylindrical case, composed of fine sand-grains, usually more or less mixed with morsels of bark and other vegetable matters. Parthenogenesis is believed by Mr. McLachlan to occur in some species of *Apatania*, of which no males have ever been seen. *Apatania muliebris*, an inhabitant of some parts of the South of England, is one of these.

Of the Sericostomidæ, the larvæ generally inhabit streams, and dwell in a free case, which is usually formed of sand and small stones. In some, such as the species of *Goëra* and *Sile*, the

case is formed as above, of coarse sand-grains and small stones, but in addition to these the larva adds larger angular stones along the sides, which give the case a very broad and depressed appearance. *Brachycentrus nubilus*, a British species, makes a quadrangular case of vegetable materials. The most remarkable cases formed by larvæ of this group are those of the genus *Helicopsyche*, several species of which occur in South Europe, and one is recorded from North America, while some analogous forms are described by Dr. Fritz Müller as occurring in Brazil. The cases of the larvæ are composed of sand-grains and small stones embedded in the silken material forming the actual case; but, unlike any of the cases already described, they are of a spiral form, exactly resembling small snail-shells, and in fact they were at first taken for the shells of small fresh-water mollusca. They appear generally to live in the water, but Professor Von Siebold found them at Lugano, in Italy, under dead leaves in a wet rocky spot.

The case formed by the larvæ of the Leptoceridæ is usually a cylindrical, slightly curved tube, composed of sand-grains, to the surface of which long twigs are sometimes attached. The

larvæ live both in standing and running water, but generally avoid strong currents. The case of the larva of *Molanna angustata*, a British species, which usually inhabits standing water, is described by Mr. McLachlan as follows:—"It consists of an inner tube, but the external aspect is very broad and flattened, convex above, with the head-end produced far over the termination of the tube, forming a cover partially protecting the larva when feeding; beneath, the case is slightly convex in the tubular portion, but the sides are dilated in a concave manner. The material employed is fine sand, but to the outside of this, above, are fixed large angular flakes of silex, and, more rarely, vegetable fragments." This larva always lives upon a sandy bottom, where its case is very difficult to detect unless the inmate moves. Two British species of *Setodes* (*S. tineiformis* and



LARVA (A), LARVA-CASE (B), COCOON (C), PUPA (D), AND IMAGO (E), OF *RHYACOPHILA VULGARIS*.

interrupta) live in cases composed solely of hardened silken secretion, with no sand or other extraneous matters attached to them.

Of the Hydropsychidæ, the larvæ live both in standing and running water, but more commonly in the latter, and they appear to be to a great extent carnivorous in their habits. Their cases are free, usually consisting of irregular oval masses of small stones, attached to the surface of larger stones at the bottom of the water. Sometimes the larvæ live gregariously under a common roof, composed chiefly of vegetable *débris* fastened together with silk, but then they make separate cases in which to pass the pupa state. The species of the genus *Tinodes*, and some others, make silken galleries upon the surface of submerged stones, &c.

The Rhyacophilidæ, which include many species, especially in the typical genus *Rhyacophila*, agree with the preceding in their general habits, and many of them frequent torrents. The pupa is enclosed in a special brown cocoon within the case.

Finally, the Hydroptilidæ, which include a great number of very minute species, some of them barely an eighth of an inch across the wings, make little cases of silk resembling seeds, to the outer surface of which a few minute sand-grains, portions of diatoms, &c., are attached. These cases have a slit at each end, and the larva can protrude its head at either of them. The larvæ inhabit both standing and running waters.

W. S. DALLAS.

ORDER LEPIDOPTERA (BUTTERFLIES AND MOTHS).

CHAPTER IX.

THE METAMORPHOSES OF THE LEPIDOPTERA.

Characteristics of the Order—EGG STATE—Structure and Development of Eggs—LARVA STATE—Shape and Structure—Stinging Larvæ—Internal Anatomy—Food—Enemies—Growth and Development—METAMORPHOSIS—Pupation of *Vanessa urticae*—Of other Butterflies—Of Moths which form a Cocoon—PUPA STATE—Structure of Pupa—Development—Emergence of the Imago.—IMAGO, OR PERFECT STATE—Wings—Neuration—Scales—Legs—Head and Body—Internal Anatomy—Food—Senses—Geographical Distribution—Collecting—Killing—Setting—Relaxing—Localities.

THE order Lepidoptera, or Scale-winged Insects,* includes the Butterflies and Moths, of which at least fifty thousand species have already been described. They may readily be distinguished from all other insects by their being provided with four wings, clothed with scales, in the perfect state. Their metamorphosis is complete—that is, they pass successively through the four stages of egg, larva (or caterpillar), pupa (or chrysalis), and perfect insect. These changes we have now to consider.

The parent Butterfly or Moth lays her eggs on the plant or other substance which is best suited for the food of the larvæ when they hatch. Some species lay their eggs singly, while others lay them in a cluster, like the Gold-tail Moth, which covers them with down plucked from her own body, or the Lackey Moth, which glues them in a ring round the small branch of a tree. In any case, they are always so placed as to ensure the safety and comfort of the larvæ.

The eggs are very interesting microscopic objects. They are covered with a hard shell, so that they are not easily injured, and their shapes and colours are very various. Some are globular, others are egg-shaped, or resemble cheeses, barrels, turbans, &c. Some are smooth, but they are more frequently ribbed, fluted, or striated in such a manner as to form exceedingly elegant and complicated patterns. They are most often greenish, but are sometimes brown, blue, red, or yellow, and are not unfrequently spotted or striped.

When the eggs are laid they are perfectly opaque, and the interior is divided into two layers, not always sharply differentiated from each other. The inner portion, however, is more liquid than the other, and in this arise "ameboid cells," or bodies of an irregular star-shape, which appear first at the upper end of the egg, and multiply until they reach the surface, when they become globular in form, and gradually extend all over it. At the same time they multiply downwards, at length becoming conglomerated into a spindle-shaped mass, in the centre of which appears a longitudinal streak.

After this stage is reached, the development of the embryo proceeds rapidly, and when the infant larva is fully formed the egg-shell frequently becomes semi-transparent, so that the occupant may be seen coiled up inside. The duration of the egg-state is sometimes variable, even in the same species; for when two or more broods of an insect appear in the course of one season, the eggs which are laid in the summer hatch in a few days, while those laid by the last autumn brood do not hatch until the following spring. But in such a case the larva is often fully developed in the autumn, and lies dormant in the egg during the winter, ready to burst from its prison as soon as the vegetation of the next season shall be sufficiently advanced to provide it with appropriate food. Sometimes, too, when young larvæ are hatched in autumn, they retire at once to winter quarters, and eat nothing until the following spring.

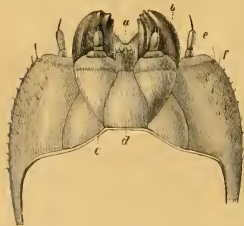
All eggs, however, do not arrive at maturity. Unfertilised eggs do not usually hatch, although parthenogenesis sometimes takes place in the Silkworm and other large Moths, while it seems to be almost the rule among some of the smaller Moths, especially in the genus *Solenobia*, the wingless case-bearing females of which may go on reproducing their kind for generation after generation, like *Aphides*, without the appearance or intervention of any male.

Lepidoptera are very subject to the attacks of parasites in their earlier stages, and many of their eggs are destroyed by small four-winged flies belonging to the order Hymenoptera and the family

* Greek : *lepis*, a scale ; *pteron*, a wing.

Proctotrypidæ. These lay their eggs (one or more, according to the species) in those of *Lepidoptera* or other insects, and the larvæ which issue from them speedily devour the contents.

If the evolved larva has escaped this danger, it gnaws its way out of its shell, and not unfrequently devours the remainder before tasting other food. In this second stage of its existence the insect is generally of a cylindrical shape, and is composed of thirteen joints, which are called "segments," and are more or less distinctly separated from each other. The head forms the first segment. It is always well marked, and is of a bony consistence, much harder than the rest of the



MOUTH OF LARVA OF THE PRIVET HAWK MOTH.

a, Upper Lip; b, Mandibles; c, Jaws. d, Lower Lip; e, Antennæ; f, Eyes.

body. The upper part consists of two lobes, separated above by a longitudinal division. The upper part of the face is called the clypeus, or shield, which varies in shape in different species, and below this is the upper lip, or labrum. Six very minute ocelli, stemmata, or simple eyes, as they are variously called, are arranged in a semicircle on each side the mouth.* Below the labrum are the mandibles, and it is worthy of notice that although *Lepidoptera* are haustellate, or sucking insects in the perfect state, they are always mandibulate in the larva. The antennæ are small, pointed, movable projections, placed at the base of the mandibles. They are generally four-jointed. Beneath the mandibles are a pair of lower jaws (maxillæ), which are soft and membranous, and fitted for holding rather than biting their food. They are furnished with two small four-jointed organs, called maxillary palpi, and behind these parts is situated the membranous lower lip, or labium, below and on the inside of which are

two small two-jointed organs, called labial palpi. At the extremity of the labium is situated a conical jointed projection, called the spinneret, from whence issue the threads used by the larva in the construction of its cocoon, and in the case of some gregarious species, its nest.

The twelve segments forming the body of the larva are covered with a soft flexible skin, which may be either smooth, granulated, hairy, or spiny. The three segments behind the head which correspond to the thorax of the perfect insect are each furnished with a pair of true legs, consisting of three cylindrical joints, covered by a horny skin, and terminated by a claw. In some species, as in the larva of the Lobster Moth (*Stauropus fugi*), these legs are of extraordinary length. If one or more of these legs should be amputated, the corresponding leg of the imago will also be more or less defective. There is often a horny plate on the back of the second segment behind the head, which is called the scutellum, and there is a triangular flap on the last segment, above the anus, which is often horny, and is called the abdominal fold. Each segment, except the first, third, fourth, and last, is provided with a small opening on each side, above the feet, which is surrounded by a horny margin. These openings are the spiracles, through which the insect breathes, and they are generally placed on round coloured spots, called stigmata. Those on the second and twelfth segments are the largest.

Besides the six true legs, the larvæ of *Lepidoptera* are furnished with from one to four pairs of fleshy "pro-legs" on segments 7—10; and an additional pair, called "claspers," which terminate the last segment. No European larva has more than sixteen legs, but the larvæ of some American *Bombyces* are said to have twenty, segments 6—11 inclusive being furnished with pro-legs. On the other hand, the larvæ of the *Geometridæ* have only ten legs, those on segments 7—9 being obsolete. Those of the *Nepticulidæ* have nine pairs of ill-developed pro-legs, but no true legs, and those of the *Limacodidæ* are entirely footless.

The pro-legs consist of two fleshy joints, and are adapted for climbing. In the case of larvæ which live exposed they are rough at the extremity, and furnished with a circle of small hooks directed inwards; but in those which live inside the stems of plants they are smooth, and provided with hooks directed outwards. In many *Notodontidæ* the claspers are replaced by two long slender appendages, which sometimes enclose retractile filaments, as in the larva of the Puss Moth (*Cerura vinula*); and in the *Drepanulidæ* the last segment terminates in a double point.

* Six is the usual number on each side in the larvæ of *Lepidoptera*, but it is not invariable.

Many larvæ are smooth and naked, or thinly covered with hair. Others are covered with a close pile, and some, like the Tiger Moths (*Arctiida*), with thick, shaggy hair. Some are tufted or spiny, while others are furnished with humps, warts, or tubercles, varying in size and position according to the species, and the tufts of hair are often placed upon such prominences. The retractile appendages at the extremity of the body of the larva of *Cerura vinula*, already mentioned, as well as the retractile fork found on the back of the neck of the larvæ of all the true *Papilionida*, are believed to be designed to drive away Ichneumon Flies or other enemies. Birds will seldom eat brightly-coloured or hairy larvæ, but they greedily devour naked larvæ of a green or brown colour, which rely rather on means of concealment than on external defences against their enemies. But some larvæ are furnished with very formidable weapons. The nests of the different species of Processionary Caterpillars (*Cnethocampa*) are dangerous to approach, on account of the fine barbed hairs of the caterpillars and a highly irritating dust, which floats about in the surrounding air. Many foreign larvæ, chiefly belonging to the *Bombyces*, are actually provided with clusters of stings, consisting sometimes of fleshy branching spines, some of which are thick and truncated at the extremity, and set with fine, sharp, stinging bristles, while others are simply pointed. Others are provided with tufts of hair, some bristle-like and others finely pointed; while the broad footless larvæ of the *Limacodidæ* are provided with spines filled with a coloured liquid, and terminating in a knob set with short sharp bristles. These fascicles of stings are darted forth by the larva whenever it is alarmed, and cause a long-continued burning pain.

The basis of the nervous system in insects consists of two double longitudinal cords running along the under surface of the body (see Vol. V., pp. 290, 291). Each of these is itself double, and the upper one is very indistinctly marked in Lepidoptera. It is in the lower one only that ganglia, or knots of nervous matter, are placed. In the larvæ of Lepidoptera there are thirteen pairs of ganglia. The anterior pair, situated above the œsophagus, or gullet, represents the brain; and the first of those situated below it represents the *medulla oblongata*. Leaving this, which Newport calls the first sub-œsophageal ganglion, the cords which correspond to the *crura* run on each side of the œsophagus into the second segment, where they form the second sub-œsophageal ganglion. Beyond this and the following ganglion, which is placed at the back of the third segment, the cords diverge to include the insertion of the first and second series of diagonal muscles; the two following ganglia, situated towards the extremity of the fourth and fifth segments respectively, completing the thoracic system. The cords are continued beyond, forming a double ganglion in each segment up to the eleventh, where the large terminal ganglion, formed by the fusion of those belonging to the eleventh and twelfth segments, is situated. In some larvæ these ganglia are distinctly separated, in which case fourteen pairs are present instead of thirteen. Great changes, however, take place in the nervous system during the pupa state, when the four thoracic ganglia fuse into two large ones, which distribute nerves to the legs and the muscles of the wings, while the two following ganglia either disappear entirely or amalgamate with the others.

The digestive system is very simple in the larvæ of Lepidoptera, in which it commences by a distinct œsophagus, which terminates by a valvular orifice in the third segment in a long muscular stomach, terminating in the pylorus and ilium. The Malpighian vessels empty themselves into the ilium, which is followed by a lobed cæcum, a very large colon, and a short rectum. Of the muscles of larvæ, suffice it to say that they are very numerous and complicated, especially in the head, in which the large muscles which move the mandibles occupy the greater part of the back and sides.

The respiratory and circulatory systems differ little from those of other insects, but a few aquatic larvæ (*Paraponyx*, &c.), are provided with branchiæ.

The food of caterpillars is very various, and there is scarcely any animal or vegetable substance which some of them will not attack. But though many species will eat a variety of plants, others are only able to subsist on one, or at most two or three; and all are more or less restricted in their food, and must die if they cannot obtain it. The great majority live exposed, and feed on the leaves of plants, but some prefer the flowers or seeds. Others are internal feeders, and live actually within the stems of plants, or even in the branches, trunks, or roots of trees, boring galleries through the solid wood, and often destroying the trees. Some caterpillars prefer withered leaves to fresh, and others, chiefly among the smaller Moths, feed on butter, leather, horn, dried fruits, corn, hair, cloth,

and other artificial or dried produce. Many of the caterpillars of the smaller Moths burrow in the leaves of trees, forming galleries or blotches, easily perceptible from their paler colouring. This habit is not confined to the small Moths. Some larger species, such as the Green Foresters (*Ino staticee*, &c.), are miners when young, and the larvæ of many two-winged flies mine in leaves in the same manner. Some few caterpillars produce galls, and others inhabit cases resembling those formed by the larvæ of the Caddis-flies, which they construct out of bits of twig, leaves, or grass. The caterpillars of the Clothes-Moths actually clothe themselves in a tight-fitting jacket, open at both ends, which they enlarge when necessary.

During this stage of its existence the insect has nothing to do but eat, and it grows very rapidly. When its skin becomes too small it is cast off, even the skin of the head and the lining of some of the internal organs being thrown off with the rest. Most caterpillars moult four or five times, although some moult only twice, and others as many as six or seven times. So serious an operation is necessarily attended by temporary weakness and discomfort, but the caterpillar soon recovers itself, and begins to eat again as fast as ever, frequently devouring its own cast-off exuvie, before it returns to its ordinary food. The colour and markings, and even the very structure of the caterpillar, are frequently changed after moulting.

Caterpillars are exposed to many enemies. The most formidable are the Ichneumon Flies, which pierce their skins, and lay an egg in each wound. These eggs soon hatch into small larvæ, which live inside the caterpillar, feeding on the fatty portions of its body, but avoiding all the vital parts. When they have arrived at maturity, they emerge from the skin of the caterpillar and form their cocoons round its dead body. Sometimes the caterpillar lives to assume the pupa state, and the Ichneumon Flies come to maturity within the pupa skin. In their perfect state they are flies, with four transparent wings and a slender body, terminated by a long ovipositor. Birds, wasps, and insectivorous animals in general destroy many caterpillars, notwithstanding the various means of defence or concealment possessed by the latter, which are sometimes truly extraordinary.

One of the most remarkable cases of protective resemblance on record was observed by Mr. Bates on the Amazons. A large caterpillar stretched its head out of a bush, and startled him by its resemblance to a small venomous Snake. He did not succeed in rearing it, but it was perhaps the larva of one of the *Sphinxide*, for these are large, smooth, and often adorned with very bright colours, such as stripes, bands, and eye-like spots.

As the larva approaches maturity it becomes possible to trace the outline of the future Butterfly or Moth beneath the skin, and traces of the wings appear just before the larva is ready to assume the pupa state. The silk-glands also become greatly enlarged in most larvæ when the time approaches for their metamorphosis. They then consist of two long tubes, opening into the spinneret, and closed at the opposite end. They are sometimes much twisted and convoluted, and extend towards the hinder end of the body, partly above and partly below the intestines. The number of convolutions depends upon the length and size of the glands, and in many Butterflies and Moths, which spin only slight cocoons or none at all, the glands are even shorter than the body of the larva, and are only curved twice. These glands are generally of a shining white colour, and can easily be distinguished from the dusky anastomosing tracheal vessels which lie above them. These organs have fulfilled their functions when the insect has assumed the pupa state, and dwindle away so rapidly that after a few days they are reduced to a mere thread.

When the caterpillar is full grown, and is ready to assume the pupa state, it ceases to eat, and its colours generally fade. Sometimes it remains motionless for several hours or days before it commences the difficult and arduous task of pupation, which is effected in various ways.

The small Tortoiseshell Butterfly (*Vanessa urticae*) may be taken as typical of those Lepidoptera in which the pupa is suspended freely by the tail. When the larva is about to undergo its metamorphosis, it selects a position which it deems suitable, and commences by spinning a little button of silk, strong enough to support the weight of its body. Having completed this work, the larva thrusts its claspers into the middle of the silk button, which projects a little, and swings itself head downwards from this support. The most difficult part of the whole process has now to be accomplished—the extrication of the pupa from the old larva-skin while the latter is thus suspended in mid-air. The larva contracts its body several times until the skin cracks along the back, and the pupa gradually

works itself through the rent by alternately dilating and contracting the rings of its body, and working the larva skin backwards towards the tail. How the tail of the apparently helpless pupa could be withdrawn from the old skin, and fixed in the silk button without the pupa itself falling, long remained unexplained, and it was always supposed that the pupa seized the old larva skin between two of the segments of its body, as with a pair of pincers, and thus worked itself upwards. But according to recent observations of Dr. Osborne this is not so, but the pupa remains connected with the old larva skin by "a membrane extending from the lining of the latter to the anterior horns of the two lateral ridges bounding the anal area of the chrysalis." Some writers regard this membrane as formed of the lining of the tracheæ, which, as well as that of the intestinal canal, is thrown off with the cast skin of the larva. Nor is the membrane the only support of the pupa, for the interior of the larva skin and the surface of the pupa are damp, if not actually wet, at this stage, and the pupa is, therefore, in part at least, upheld by capillary attraction. The chrysalis then stretches up its tail towards the button of silk, and by a series of violent efforts succeeds in reaching it, and in fixing itself by the small hooks with which its tail is provided. It then whirls itself round several times, first in one direction and then in the other, in order to secure its hold, and to fix the hooks as firmly as possible. During this process the connection between the pupa and the cast-off skin of the larva is almost always severed, and the latter falls to the ground.

The pupation of the larvæ of those Butterflies in which the pupa is attached to a stem, horizontally or vertically, by the tail and by a girth of silk round the body, is effected in a very similar manner. Some larvæ, like those of the *Pierinæ*, are sufficiently flexible to attach a thread on one side of their body, and then carry it over, and fasten it on the other side, repeating the operation as often as necessary; but in the case of the *Lycenidæ* the girth is spun first, and the larva slips its head under afterwards. The *Papilioninæ*, on the other hand, spin their girth, holding the separate threads in their claws until the girth is strong enough, when they slip them over their heads. This arrangement is necessary on account of the great risk of entangling the numerous threads of which the girth is composed.

The larvæ of many Moths construct a hollow ball of silk, called a cocoon, in which to pass the pupa state, and it is from the cocoon of the Silkworm and other Moths that the silk of commerce is derived. Some cocoons, like that of the Silkworm are entirely closed, while others, like that of the Emperor Moth, are partially open at one end, being constructed somewhat after the manner of a weir, so that while they form no impediment to the egress of the enclosed Moth, an enemy cannot force its way in from the outside. The larvæ of many *Sphingæ*, &c., construct a cell in the ground, lined with agglutinated earth and silk, and those of the Goat Moth and other internal feeders, form their cocoons in the solid wood of trees, forming a tunnel leading up to, but not breaking through, a partition opening upon the outer air. Some cocoons, like those of various *Notodontidæ*, are attached to the bark of trees, which they closely resemble, and are as hard as wood. Many larvæ which spin cocoons construct them in the autumn, and lie dormant till the following spring, without assuming the pupa state till then.

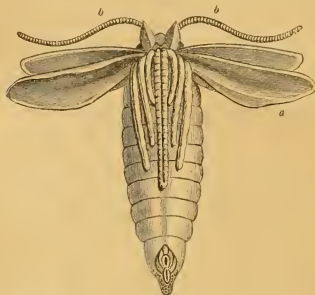
Cocoons are not always made of silk alone. It has already been mentioned that cells made underground are partially formed of agglutinated earth. Hairy caterpillars often weave their hairs into their cocoons, and others employ fragments of leaves, moss, lichen, or comminuted wood. Many larvæ, however, scarcely construct any cocoon, forming their pupæ between leaves or even on the surface of the ground, often without any preparation. Many of the large foreign *Saturniide* make their cocoons within a leaf, which they connect with the branch by a strong silken band several inches long, running along the leaf-stalk, so that even if the stalk becomes detached from the branch, the leaf cannot possibly fall to the ground.

It is believed that the object of cocoons is not warmth, but protection; for the temperature within does not exceed that of the surrounding earth or air. Protection, however, is not their only use; for the efforts which the insect makes to escape, and the pressure which the cocoon exerts upon it, are so essential to its development, that pupæ prematurely removed from their cocoons often produce only crippled specimens.

The pupa is generally of a brown colour, but those of Butterflies, which are exposed to the sun and air, are sometimes green, yellow, or metallic. The rudiments of the perfect insect, which can

only be detected in the larva state by a careful and difficult examination, are now easily to be discerned on the outside of the horny envelope of the pupa. But the pupa has no other limbs, and is usually incapable of any function of life, except breathing, or of any motion, except a slight wriggling of the segments of the abdomen. But there are exceptions; some pupæ are able to move about in their cocoons, and those formed in the trunks of trees are provided with small hooks by which they can work themselves along their galleries, and push the head of the pupa through the partition, so that when the Moth emerges it finds itself completely at liberty. The pupa of a Cuban Moth (*Conchylodes diphtheralis*) lies on the ground without any protection, but possesses the power of leaping actively about.

A pupa consists of the thorax, which is the thicker portion, and of the abdomen, which consists of nine movable segments jointed together. The seams in the thorax more or less distinctly indicate



CHRYSLIS MAGNIFIED AND PARTIALLY OPENED TO SHOW
RUDIMENTARY WINGS (a), ANTENNÆ (b), AND OTHER
ORGANS.

the parts of the future Butterfly. The head is visible as a slight swelling in front. It is pressed downwards, and the eyes are visible on each side. Behind and above this is the thorax; and the lower joints of the two first pairs of legs are placed on the under side in front, on the sides of the head. The antennæ pass round the eyes, and run backwards outside the middle pair of legs. The wing cases, which vary in length in different species, lie on the sides of the pupa. In the large *Sphinges*, the proboscis is often furnished with a separate sheath, sometimes convoluted, lying in front of the breast.

The position of the spiracles is the same in the pupa as in the larva; but not only are the external organs of the future imago developed during the pupa state, but the digestive and nervous systems are profoundly modified, assuming the form which they present in the perfect insect.

During the first stages the pupa appears to be filled with a milky fluid, in which the rudiments of the future insect can scarcely be distinguished; but these rapidly acquire consistency, an evaporation, or rather transpiration, taking place constantly, by which the weight of the pupa is eventually much reduced.

The duration of the pupa state is very different in some insects: but except in the case of summer broods of double-brooded insects, when it frequently lasts only a few days, it extends over several months, for the insect usually passes the winter in this condition. In some cases, especially in the Small Eggar (*Eriogaster lanestris*), the pupæ do not all disclose the perfect insect the same season; but the insects of the same brood appear a few at a time each year, up to fourteen or fifteen years afterwards. The reason for this is obvious in the case of the Small Eggar, for the Moth appears during the inclement month of February, and if all the pupæ belonging to the same brood disclosed the Moth during a single season, the species would be liable to extinction in the event of unusually severe weather.

When the Butterfly or Moth has arrived at maturity, the pupa cracks along the seams, and the perfect insect works itself out, discharging a few drops of fluid at the same time. In some insects this is of a reddish colour; and when the insects were unusually numerous the red spots used occasionally, in superstitious ages, to give rise to the idea that a shower of blood had fallen. In the case of insects enclosed in a cocoon this fluid serves to moisten the silk, or to exert a chemical action upon it (for it is acid, at least in some cases), in order to facilitate the escape of the Moth. Some of the larger *Bombyces* are actually provided with a strong spine under the wings, which helps them to force their way out of the cocoon. As the cocoon is useless for mercantile purposes after the emergence of the Moth, silk-growers always kill the insect before unwinding the silk, by throwing it into boiling water, which likewise renders the silk itself more manageable.

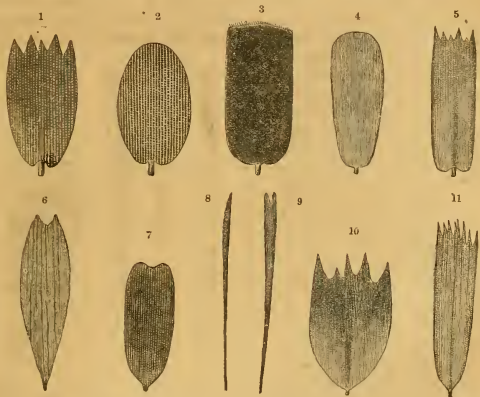
When the perfect insect has quitted the cocoon it is limp and weak. Its abdomen is thick and heavy, and its wings are in a rudimentary condition, but it crawls to a position where it can allow them to hang down, when they can almost be seen to grow, so rapidly do they enlarge to their full size and beauty, in consequence of a fluid being driven through the nervures, which subsequently serve the purpose of air-tubes. The insect then flies away to seek its mate.

In the perfect state, a Butterfly or Moth has four wings covered with scales. In some groups of Moths, however, the males only have developed wings, those of the females being rudimentary, and in almost all species the females are less active than the males. The interlacing nervures, or air-tubes, by which the wings are traversed, form an important aid to the classification of groups. In the centre of each wing we generally find an open space, called the discoidal cell. This is bounded in front by the sub-costal nervure, and behind by the median nervure. Between the costal, or front of the wing, and the sub-costal nervure runs another nervure, called the costal nervure; and between the median nervure and the inner margin (that part of the wing nearest to the body when the wings are laid back) runs another nervure, called the sub-median nervure. These run into the costa or to the lower part of the hind margin without forking; but the sub-costal and median nervures both throw off several branches—or nervules, as they are called—to the costa or to the hind margin, which is the side of the wing farthest from the body. Generally the nervures completely surround the discoidal cell, but in some cases there is an open space at its extremity; and then the discoidal cell is said to be open. But the neururation of the wings is much more complicated in some Moths, the discoidal cell being divided longitudinally, or else small cells may be formed beyond it by the junction or crossing of nervures. When most complicated, the neururation resembles that of the Caddis-flies (*Trichoptera*). But the colours and patterns of the wings are so various that the study of structural characters is less necessary than in other groups of insects.

The muscles which move the wings of Lepidoptera differ little from those of other insects. There are two sets which depress the wings: firstly, a double dorsal muscle, running longitudinally upwards in the meso-thorax; and, secondly, the dorso-ventral muscles of the meso- and meta-thorax, which are attached to the articulations of the wings above, and to the inside of the thorax beneath.

Between these lie the muscles, which raise the wings, and which run from the inner side of the back of the thorax to the legs. During flight, the thorax expands and contracts rapidly and constantly.

The scales which cover the wings resemble a fine dust, which easily rubs off on the fingers; but if the wing is placed under a microscope, it is found to be covered with a great number of elegantly formed scales of various shapes, some of which are represented on the adjoining woodcut. These are laid over each other, like the tiles on a roof, and are attached to the wing by a small stalk, which, in



SCALES OF DIFFERENT GENERA OF LEPIDOPTERA.

1, 2, *Papilio machaon*; 3, 4, *Morpho menelaus*; 5, *Cycloides arcythus*; 6, *Sphinx apiformis*; 7, *Zygra bifidula*; 8, 9, 10, *Sphinx ligustri*; 11, *Pterophorus pentadactylus*.

some *Morphinae*, &c., seems to be fixed on the principle of a ball and socket joint. The scales consist of a double membrane, finely striated. Between the striæ, and parallel with them, are arranged pigment cells; but this is not the sole cause of their beautiful colours, for the edges of the scales frequently refract the light, and thus produce the most brilliant metallic lustre.

If the scales are rubbed off a colourless membrane remains, with branching nervures running through it. In this state it does not greatly differ from the transparent wings of other insects, except for the sockets from which the scales have been removed.

Butterflies and Moths have six legs in the perfect state, but in some families of Butterflies the front legs are rudimentary, and in the males of a few Moths the hind legs are shorter than the others.* The tibiae are not unfrequently furnished with spines in the middle or at the extremity. The tarsi are usually five-jointed, and generally terminate in a pair of claws.

Having noticed the legs and wings, it now becomes necessary to describe the structure of the head and body, before proceeding to notice the internal anatomy. As in all other insects, a fully-developed Moth or Butterfly is composed of thirteen divisions, or segments, the first of which forms the head, segments 2—4 form the thorax, and the remainder form the abdomen. The distinction between the thorax and abdomen

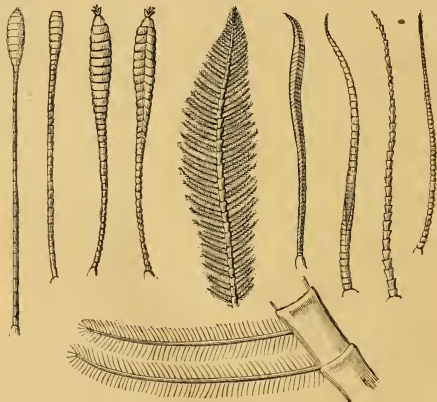
MOUTH OF THE PRIVET HAWK MOTH.

a, Upper Lip; b, Mandibles; c, Proboscis; d, Under Lip; e, Antennæ; f, Eyes.

is always well marked in the perfect insect, although it is not sharply indicated in the larva.

The head is rounded, and generally rather broader than long. There are two large eyes on each side, formed of a great number of facets, and therefore called compound eyes. Their surface is

covered with short hairs in some species, and is naked in others. In addition to these, there are sometimes two small simple eyes (often called stemmata, or ocelli) situated on the vertex or top of the head; but these are not present in many groups of Lepidoptera. The forehead is sometimes provided with a small horn or crest. The antennæ are placed in two small hollows near the eyes, and appear to be organs of touch, hearing, and smell. They are composed of a great number of joints, and in Butterflies they are long and straight, and are thickened into a club at the extremity. In Moths the antennæ are sometimes simply filiform or thread-like, but are more frequently provided with appendages, varying in shape and size. The antennæ are called dentated, or toothed; serrated, or saw-like; pectinated, or comb-like; and plumose, or feathery, according to the various appearances assumed by these appendages. The sexes often differ in the development of the antennæ,



ANTENNE OF LEPIDOPTERA, GREATLY MAGNIFIED.

* The aborted hind legs of the male of *Hepialus* are said to be used as brushes to scatter round him the odour contained in two pouches with which his abdomen is provided.

and in this case those of the male are always more developed than those of the female. An hermaphrodite of such a species presents a very remarkable appearance when the antenna on one side is pectinated, and that on the other is simple. The antennae are often clothed with hair or scales, and the basal joint is larger and thicker than the others, except in the Butterflies and *Sphinxes*. In some genera of *Tineina* it is expanded into a scale, which partially covers the eye when at rest, and is called the eye-cap.

The parts of the mouth which are best developed in Coleoptera and Hymenoptera are very slightly developed in Lepidoptera, and are almost rudimentary. The only organs which demand attention are the large and overhanging clypeus, the proboscis, and the labial and maxillary palpi. The upper part of the mouth is formed by the small labrum, which is nearly concealed by the overhanging clypeus, and the rudimentary mandibles. Below these is the proboscis, or tongue, which is generally horny. It forms a spiral tube when not in use, but can be stretched out and plunged into the corolla of a flower when the insect desires to feed. It is made of two separate pieces throughout its entire length, so that it can be separated and cleaned if there is any danger of its becoming clogged. In many *Bombyces* the proboscis is nearly obsolete, whereas in the *Sphingidae* it is often several times as long as the body, and is sometimes liable to become fixed in flowers and broken. The proboscis corresponds to the maxillae of other insects. At the base of the proboscis are placed the maxillary palpi, which vary in shape and size, and are usually composed of three joints, the last being generally pointed. The lower portion of the mouth is formed by the small triangular labium, on which the labial palpi are placed, which consist of from one to three joints, and are rudimentary in most of the larger Lepidoptera.

The structure of the thorax differs little from what we find in other insects. The prothorax is very narrow above, but is broader below, where the first pair of legs are attached to it. The mesothorax is very large, and is divided longitudinally above. It bears the first pair of wings and the second pair of legs. The former are attached beneath small thin plates called scapulae. The metathorax is short, and generally consists of five small plates above. The last pair of wings and legs are attached at the sides and on the lower surface respectively.

The abdomen consists of nine movable segments, the hinder margin of each covering the base of the next. The last segment contains the anus and the sexual organs. The male organ is enclosed by two folds, and the female is sometimes provided with an ovipositor. Scent-fans, or scent-pouches, are sometimes placed at the base or extremity of the abdomen in the males.

The whole body is more or less densely clothed with hair or scales, which sometimes form conspicuous crests on the thorax and abdomen.

The nervous system of the larva becomes much modified in the perfect insect. All Lepidoptera have two cephalic ganglia, and the supra-oesophageal ganglion is furnished with convolutions. In most cases there are two distinct thoracic ganglionic masses, the first simple, and the second composite. Sometimes these are close together, and at other times they are more or less widely apart. There are always four abdominal ganglia, the only known exception being in the case of *Heptalus humuli*, which has five.

The digestive system is also modified in the perfect insect. The intestine is much longer than in the larva, and the long and narrow oesophagus is dilated into a large crop in the thoracic segments, which is generally filled with air. The stomach is short, oval, and very muscular, and the ilium is long and narrow, and forms several convolutions, and is covered by the Malpighian vessels throughout its whole length. The colon is large, and is often dilated into a caecum in front. The salivary glands are simple elongated tubes, and correspond to the silk glands of the larva.

The food of Butterflies and Moths in the perfect state consists of the honey of flowers, honeydew, the exuding sap of trees, over-ripe fruit, &c. The great Death's Head Hawk Moth (*Acherontia atropos*) will sometimes enter beehives, to feast upon the honey. Nor is this the only enemy which Bees have to fear among Moths; for there are several species of small Moths, the caterpillars of which feed on wax in bee-hives, and often commit great havoc. Many Butterflies are attracted by putrid substances, and others are fond of assembling, sometimes in great numbers, to suck up the moisture from the damp ground.

The senses of Lepidoptera are very acute. They are not unfrequently attracted by artificial or

painted flowers, evidently mistaking them for real. A large number are provided with organs fitted for producing a sound, though it is inaudible to our ears in most cases, although the Death's Head Hawk Moth, and several allied species, are capable of uttering a very audible squeak. The males of those Moths which have highly-developed pectinated antennæ will gather round a box which contains a virgin female, and it is believed that they can be thus attracted from a distance of a mile or more. The males of various species are also provided with tufts of hair, which emit a distinct odour. These are sometimes placed between the wings, and sometimes on the antennæ, legs, or abdomen. This is specially noticeable in the British Privet and Convolvulus Hawk Moths (*Sphinx ligustri* and *convolvuli*), the males of which emit a musky scent. In these cases the odour is believed to be attractive rather than protective, but some of the insects which are refused by birds appear really to owe their immunity to their disagreeable smell or taste, and sometimes the same insect emits two distinct odours from different parts of its body—one protective, and the other, perhaps, attractive.

Insects so voracious as caterpillars frequently commit great havoc in our fields and gardens. Perhaps the most formidable of all are those called "Cut-worms" in America, which live beneath the surface of the ground, and eat through the roots of plants which come in their way. Most of these develop into dark-coloured Moths, belonging to the genus *Agrotis*. As a set-off against the mischief caused by Butterflies and Moths, we have the valuable product called silk; and in some parts of Australia cakes formed of a particular species of *Agrotis* form a staple food of the inhabitants. We do not eat insects in Europe, but may derive much pleasure from studying their structure and habits, and from admiring their beauty.

Butterflies and Moths are found in all parts of the world, and are exceedingly numerous in species. There are about 2,000 different kinds in the British Islands, out of which only sixty-five are Butterflies and the remainder are Moths. Islands are always poorer in species than continents; and if we take Europe into consideration, we find 5,000 species of Moths, and nearly 300 of Butterflies on the lists. Iceland alone is said to produce no Butterflies, but only a few Moths, but both Butterflies and Moths (though not more than about a dozen different kinds) have been met with in the polar regions, as far north as our explorers have yet penetrated. Insects are far more numerous in the warmer parts of the world, abounding most where the vegetation is most luxuriant and varied. About 10,000 species of Butterflies and 40,000 of Moths have been described at present, and hundreds of new species are added to our lists every year. Butterflies are particularly numerous in tropical America, and more than half of all the species known inhabit this part of the world. Upwards of two thousand different kinds have been collected in the valley of the Amazon alone, but a great number of these are small and inconspicuous species, and it is the aggregate and not the comparative number of large and brilliant species which makes us consider size and colour as so characteristic of the Butterflies of the Tropics. If we compare two species belonging to corresponding groups, one of which is found in Europe or Japan, and the other in India, we shall generally find that the Indian insect is the smaller. Nor does the abundance of species depend on heat alone, but rather on the variety of the vegetation, and therefore Butterflies and Moths are far more numerous in Switzerland, where the variety of elevation gives rise to a greater variety of vegetation, than in the peninsulas of Spain or Italy. Andalusia, with its sub-tropical climate and vegetation, hardly produces more Butterflies than Sweden. Many of those which occur on the plains in Lapland are met with in the Alps in Switzerland; and many common Central European Butterflies are mountain insects in Andalusia, and the number of species peculiar to the extreme South of Europe is comparatively small, and by no means compensates for the almost total disappearance of the numerous Alpine species of Central Europe. The opposite coast of North Africa is even poorer in species than Southern Spain.

Before closing this chapter, some of our readers may wish for a few hints in regard to forming a collection of Butterflies and Moths. It is easy to make a beginning, and the utensils required are neither numerous nor expensive—a net, pins, setting-boards, and boxes being everything which is required in the first instance.

The most convenient kind of net is, perhaps, the ring-net. This consists of a net of green gauze, attached to a ring fixed on the end of a stick. The net should be gradually tapering, but rounded at the end, so as to contain no corners, and should be about three times as long as the width of the ring. It should not be sewn directly on the ring, but attached to a strip of some stouter substance at the

top, which can be sewn on the ring, for this will make the net last much longer. The ring should be about a foot in diameter, and it is usual to employ a jointed iron ring, which can be folded up when not in use and put in the pocket. It may be made to screw on the end of a common walking-stick, for which a cap must be provided, to screw on when the net is not wanted, to keep out the dirt. If a net is required in a hurry, it may simply be sewn on a ring of willow-twigs, and fixed at the end of a forked stick, and such an arrangement will answer very well on an emergency. A very portable but more expensive net is the umbrella-net. This is formed of a large ring of whalebone, with a stick through the middle. It is made to open and shut like an umbrella, and goes into a similar case when not in use; but it is too short for many purposes, and the stick in the middle is another objection.

Having caught your Butterfly or Moth, you next proceed to secure it. The pins used by entomologists are long and slender, and are sold by dealers in objects of natural history under the name of "Entomological pins," for those used for common purposes are generally too short and thick. The pins are made of different sizes; choosing one proportioned to the size of the insect, it must be pinned exactly in the middle of the thorax. You then pin it into a small box, lined with cork, which you carry in your pocket. But if you like to bring your specimens home alive, as can be done in the case of most of the smaller Moths, you must be provided with a supply of strong chip-boxes, into which to put your captures. You must take care only to put one insect into each box, and to keep the full and empty boxes in separate pockets, to avoid mixing them. But Butterflies, *Sphinxes*, *Bombyces*, and, generally speaking, all large and active insects, must be pinned on the spot; for if you put them into a box they will knock themselves about in it, and when you open it you will find only a mass of fluff, and your specimen spoiled.

In putting these insects to death, of course the speediest means will be adopted. Small or slender-bodied insects, including most Butterflies, may be killed by a sharp nip under the wings, but this method will not answer for thick-bodied insects. These may be killed by being pierced with a pin dipped in a strong solution of oxalic acid, or may be stupefied with chloroform, and afterwards killed by being placed in a jar half filled with bruised laurel leaves, and tightly stoppered. Ammonia, sulphur, and cyanide of potassium, which some collectors use, are liable to discolour many insects. If you are on a journey, and short of boxes, you may keep your insects in "papers." These are constructed of square pieces of paper folded diagonally, and doubled over at the side, so as to form a triangular envelope open at one end. In this case the insect is simply killed and dropped into the envelope, which is then folded over and put away loosely in a box with cotton wool and a little camphor. But this method is not to be recommended when you are able to pin and set your insects at once.

In order to set your captures you will require setting-boards. These are proportioned in width to the size of the insects to be set, and may be of any convenient length; those most commonly used are about ten inches long. There is a corked groove in the middle to receive the body of the insect, and the sides are also formed of cork. The boards may be flat if you prefer it, as used on the Continent, but they are generally bevelled off on each side in England, which gives the wings of the insect a sloping appearance in the cabinet.

Having chosen a board proportioned to the size of the specimen you wish to set, you pin the Butterfly as nearly as possible in the middle of the groove. The body lies in the groove, and you then spread out the wings on each side in as natural a position as possible, and keep them in their places by pressing them down with strips of cardboard, secured by a pin at one or both ends. Only practice will enable you to do this neatly, and you will soon find that some insects are much easier to set than others.

It will sometimes happen that your specimens pinned in the field become too stiff to set properly when you get home. These, as well as any specimens which have been pinned or papered and left unset, will require to be relaxed. This is effected by putting them into any covered vessel partly filled with damp sand or sawdust, and placing them in a warm place. In a day or two they will become sufficiently limp to set, and must then be attended to at once, for if left too long they may become mouldy or rotten. In all cases insects must be left on the setting-boards till their wings have completely stiffened in the position which you have given them.

When the specimens are thus prepared they must be placed in store-boxes, or in cabinets made

for the purpose. The boxes or cabinet-drawers must be lined with cork, and the latter are usually provided with tightly-fitting glazed lids. Any box used for insects should be tightly-fitting, and furnished with plenty of camphor, or mites and other pests will soon reduce your collection to dust. Many preventives have been recommended, but camphor, plentifully used, and the supply well kept up from the first, appears to be the most successful of all. Butterflies in glass cases would form a very pretty ornament on the wall; but although they will preserve their colours for more than a century if kept in the dark, they bleach very rapidly if constantly exposed to the light.

You will find Butterflies and many Moths flying in gardens and other places where there are plenty of flowers, and these may be captured with the net. As it grows dusk the Butterflies disappear, but the Moths become more numerous, and they may be caught in the same way until it grows too dark. Later in the evening it is a good plan to daub over the trunks of trees with some sweet compound—a mixture of brown sugar and beer, flavoured with a few drops of rum, is most commonly employed—and afterwards visit the trees with a lantern and catch the Moths which are attracted by the bait. This mode of collecting is called “sugaring,” and is somewhat uncertain, as on some nights the sugar will be covered with Moths, and on others you will scarcely find one.

In the country many Moths may be attracted by a light placed at an open window. During the day you will not see many Moths, except those which are habitually day-flying species, but if you look about a little you will sometimes find Moths sitting on the shady side of the trunks of trees, especially early in the day, and by beating a hedge to windward you will generally dislodge a great variety, chiefly slender-bodied or small Moths, which you can catch as they fly out.

There are no Butterflies to be found on the wing during the depth of winter, but there are several species of Moths which only appear at this season of the year, and a considerable variety may be caught in the evening, both in early spring and late autumn, at the blossoms of the willow and the ivy respectively.

CHAPTER X.

BUTTERFLIES.

The Brush-footed Butterflies—Butterflies distasteful to Birds—Mimicry—Transparent-winged Butterflies of South America—Brown Butterflies frequenting Marshes and Meadows—Silvery Butterfly from Chili—The Great Blue Butterflies of South America—Great Owl-like Butterflies Flying at Twilight—An African Group of Spotted Butterflies—Passion Flower Butterflies of South America—The Fritillaries—The Comma Butterfly—Leaf Butterflies—Dissimilarity of the Sexes in some Butterflies—Red, Blue, and Green Butterflies of South America—Elegant Flight of the White Admiral—Lofty Flight of the Purple Emperor—Long-snouted Butterflies—A large Group of Small and Elegant Butterflies almost peculiar to South America—Copper Butterflies—Small Blues—Hairstreaks—Long Tails of some of the Allied Eastern Species—The White and Yellow Butterflies—Some of this Group Brightly Coloured—Mimicking South American Butterflies—Small and Large Yellow Butterflies of the Tropics—Garden Whites—White Indian Butterflies with Red Spots on the Under side—Indian Butterflies with the Front of the Wing Ridged like a Saw—The Brimstone and Clouded Yellow Butterflies—Orange-tips—Swallow-tailed Butterflies—The Apollo Butterflies—Magnificent Tailed Butterflies from the Himalayas—The Great Bird-winged Butterflies of the East—A Croesus among Butterflies—South American Butterflies with Iridescent Spots—Mimicking Butterflies again—Gold-dusted Butterflies—Great Blue Butterflies of the Eastern Islands—The True Swallow-tailed Butterflies—Extraordinary Difference between the Sexes of an African Butterfly—Very Long Tails of a Small Indian Group—The Skippers—Their Resemblance to the Moths—Tailed Skippers of South America—The Fire-tailed Skippers—The Grizzled Skipper—The Pearl Skipper.

The first five families of Lepidoptera are called Butterflies in England, and their antennæ are nearly always thickened into a knob at the extremity. All the European species, and the great majority of the foreign ones, fly only by day, though some species prefer the shades of the forests, and some tropical Butterflies fly only at dusk. There is reason to believe that others fly more or less at night, but this requires to be confirmed by further observations.

FAMILY I.—NYMPHALIDÆ.

Half the known Butterflies belong to the first family, that of the *Nymphalidæ*, which is divided into several sub-families. The front legs of these Butterflies are rudimentary in both sexes, forming a

kind of paw, quite useless for walking, and hence some writers have called them Brush-footed Butterflies. The pupa is generally suspended freely by the tail. The caterpillars differ in structure, some being hairy or spiny, others furnished with long fleshy filaments, and others again are almost naked, with a forked tail.

The first group, the *Danainæ*, is almost confined to the tropics. Most of the species of *Danaïs* inhabit the Old World, though a few are met with in America, one species being abundant over almost the whole of that Continent.

They are large broad-winged Butterflies, generally either of a warm reddish-tawny colour, with blackish borders, or brownish-black, the centre of the wings being green, divided by the veins. The only European species (*Danaïs chrysippus*) is found in Greece, but is also one of the commonest Butterflies in the East Indies and Africa. It is reddish-tawny, with black borders dotted with white, and the tip of the fore wings is broadly black, and marked with a band of large white connected spots. There are also four black spots in the middle of the hind wings. There is scarcely any Butterfly which is more interesting than this insect, as it illustrates some of the most remarkable problems of insect life in a pre-eminent degree. The *Danainæ* are rarely attacked by birds. Their integuments are exceedingly tough, and most of them possess the power of protruding two strongly-smelling processes from the abdomen. But it would scarcely be imagined beforehand that the colours and markings of a species thus protected would be repeated, with more or less accuracy, in six or eight other Butterflies and Moths, bearing a much closer resemblance to the species which they thus



1, DANAÏS CHRYSIPPUS; 2, HYPOLIMNYS MISIPPUS, MALE; 3, DO., FEMALE.

"mimic" than to any of their own allies. What is still more strange is that in several of these instances it is the female only which resembles the species "mimicked," the male being utterly different. The principal species which thus "mimic" *Danaïs chrysippus* are as follows :—(1) *Elymnias undularis*, belonging to the sub-family *Elymniinae*. In this species the male is of a rich brown, with bluish marginal spots, while the female is tawny, with broad brown borders spotted with white on all the wings. On the fore wings the white spots coalesce into a band towards the tip. (2) *Argynnis nippe*. This species, which belongs, like the two following, to the sub-family *Nymphalinae*, has a tawny or fulvous male, spotted with black, and resembles its allies, the ordinary Fritillaries; but the female is paler, with a black border and a broad black tip, crossed by a white bar like *Danaïs chrysippus*. *A. nippe* is a common East Indian species, but the Australian form (*A. inconstans*) has a female resembling the male. (3) *Hypolimnys misippus*. This case is

more remarkable than the last, for the male is of a rich brown colour, with a large white spot on each wing, shading into blue at the edges, while the female is scarcely to be distinguished from *D. chrysippus* at first sight, except that there is only one black spot instead of four on the hind wings. There is a species of *Danais* closely allied to *D. chrysippus*, in which the white transverse band at the tip of the fore wings is wanting (*D. dorippus*), and there is a variety of the female of *H. misippus* corresponding to it (*H. inaria*), in which the white band is also wanting. (4) *Euphadra eleus*. Most of the species of this genus are green and black, but *E. eleus* is rich tawny, with black borders spotted with white, and a white bar across the tip of the fore wings. (5) *Papilio merope*. This Butterfly, which is a creamy-white Swallow-tail with black borders, is common in Africa, and the form found in Madagascar (*P. meriones*) has a female similar to the male, but no female resembling



EUPHLEA MIDAMUS: A, MALE; B, FEMALE.

the male has ever been found on the continent of Africa, where the females are tailless Butterflies, resembling several different species of African *Danainæ*, and one of these (*P. dionysus*) has a close resemblance to *D. chrysippus*. (6) *Caryatis phileta*. This insect, a Moth allied to the *Lithosiidae*, likewise reproduces the colours of *D. chrysippus*, being of a rich tawny, with black borders spotted with white.

In addition to the scent-glands at the extremity of the abdomen, the males of most species of *Danais* and *Euphlea* possess a patch of raised scales on the hind wings, which is likewise a scent-producing organ.

The genus *Euphlea* is confined to the tropics of the Old World. The species are generally of a rich dark brown, with bluish-white spots near the borders of the wings and in the middle of the hind wings beneath, and are often splendidly glossed with purple. The wings are longer and narrower than in *Danais*.

With the exception of *Danais*, all the South American Butterflies now included in the *Danainæ* were formerly classed with the *Heliconinæ*, on account of their superficial resemblance to the genus *Heliconius*. They are insects with very long and slender bodies, and very long and narrow wings, and have sometimes been compared to Dragon-flies. The greater number of these Butterflies belong to the genus *Ithomia*, and a large proportion are more or less transparent, except on the borders of the wings. Some of these are mimicked by *Pierinæ*.

The second sub-family of the *Nymphalidae*, the *Satyrinæ*, contains at least 1,000 species, but most of these are small or middle-sized Butterflies, of sombre colours. The great majority are marked with eye-like spots on the under surface of the wings, and sometimes on the upper surface also. Nearly one-third of the European Butterflies belong to this sub-family, but they are by no means so well represented in other parts of the world. Their caterpillars are generally green,

with a forked tail, and feed on different kinds of grasses. The Butterflies frequent marshes, meadows, and mountains, and many are among our commonest Butterflies, flying in every field. Many species of the genus *Erebia* are found in the Alps, the great majority of which are brown, with a row of more or less contiguous red spots towards the margins, marked with a series of black spots, which often, again, show a small white dot in the middle. The Scotch Argus Butterfly (*Erebia medea*) is the best known representative of this genus in Britain. Some foreign *Satyrine* are of a brilliant blue, though this colour is rare in the sub-family; but one of the most remarkable Butterflies known, as regards colour, is *Argyrophorus argenteus*, a Chilian insect, which is of a uniform pale silvery colour above.

The small sub-family of the *Elymniine* consists of the two genera *Elymnias* and *Dictis*. We have already noticed the female of *Elymnias undularis* as one of the mimics of *Danaus chrysippus*. All the species of *Elymnias*, except two, which are African, are East Indian or Malayan. They are generally dark-coloured insects, averaging about three inches in expanse; the fore wings are often spotted with blue and white, and the hind wings are bordered with orange. Most of the species are striated with brown on the under side, and the group has a strong family likeness, which renders it easy to recognise it. Nearly all the *Elymniine* mimic other Butterflies in the arrangement of their colours on the upper side of the wings, but their wings are always dentated, and often angulated, whereas all the Butterflies which they superficially resemble have rounded wings.



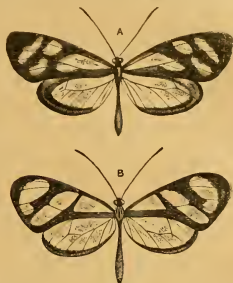
EREBIA EURYALE.

A white band across the centre of the wings only enhances its beauty. The female sometimes resembles the male, and sometimes, as is often the case in *Morpho*, is of a tawny or orange colour. Some of the species of *Morpho* fly near the ground, and frequently settle, but nearly all the largest and most splendid species fly at a great height.

The next sub-family, the *Brasoline*, consists entirely of tropical American species, but these are dull-coloured Butterflies, which fly at dusk. The great Butterflies of the genus *Caligo* resemble *Morpho* in size and appearance, but are brown, with the upper side of the wings suffused with dull blue. The under

surface is curiously marbled and speckled with brown and grey, and on the under side of the hind wings is an enormous oval dark spot, in a broad pale ring, resembling an owl's eye.

The sub-family *Acreine* chiefly contains African species of the genus *Acrea*, though one or two inhabit India or Australia, and the genus *Actinote* is South American. The wings of the *Acreine* are



A, LEPTALIS THEONOE; B, ITHOMIA FLORA.



MORPHO CYPRIS.

rather long, and are generally of some shade of fulvous, with black spots, or black with white or yellowish markings; and the hind wings are either striated or spotted with black at the base beneath. Although these Butterflies are not closely allied to the European Fritillaries, yet they completely replace them in Africa, resembling them not only in colour and appearance, but also in the spiny larvæ. The fore wings of several species of *Acraea* are more or less transparent; in others the wings are entirely opaque. In *Actinote* the wings are always opaque, and destitute of the black basal spots so conspicuous in *Acraea*, but the hind wings are always strongly striated, at least on the under surface. The colouring, too, in one section of this genus is very dissimilar to that of *Acraea*, being bluish-black, with the centre of the fore wings pink or red, this colour sometimes extending to the base.

The *Heliconiæ* are a group of South American Butterflies, much resembling the *Acraeinae* in structure, but their wings are much longer, and are generally rounded at the extremity. Their closed wing-cells will prevent their being confounded with the typical *Nymphalinae*, and although some of them closely resemble the American *Danainæ*, which were formerly classed with them, the submedian nervure of the fore wings is simple in the *Heliconiæ*, and double in the *Danainæ*. Their caterpillars are spiny, like those of the *Acraeinae*, and many of them feed on different species of passion-flower.

The genus *Heliconius* includes a great number of beautiful species. Some are black, with a large red blotch on the fore wings. Sometimes this is the only marking, as in *H. melpomene*; but in other species the hind wings are rayed with red, or marked with a basal stripe of yellow or white. In other species the fore wings are marked with yellow, and the hind wings are red, or banded with red. *H. charithonia*, the commonest species in the West Indies, is black, with yellow stripes on the wings; other species are black and fulvous, spotted or banded with yellow, and many of these resemble some of the larger opaque species of American *Danaina*, both in colour and markings.

The species of *Heliconius* vary from two to four inches in expanse, and the antennæ are long and slender. The only other genus of this sub-family (*Eueides*) has much shorter antennæ, and the species, which are generally black and tawny, varied with dull yellow, seldom exceed an inch and a half in expanse.

The great sub-family of the *Nymphalinae*, which comprises about 130 genera of Butterflies, exhibiting every variety of colour and pattern, differs from all the foregoing groups, except the *Morphinae*, by the discoidal cell being open, or imperfectly closed, either in all the wings or in the hind wings only.

The first two genera, *Colenis* and *Dione*, are long-winged South American Butterflies, the caterpillars of which feed on passion-flowers, vanilla, and other tropical plants. They resemble the *Heliconiæ* considerably in size, shape, and habits, and form a very good connecting link between these and the *Nymphalinae*; and some entomologists regard them as more properly belonging to the former sub-family. The species of *Colenis* are fulvous above, more or less banded with black. On the under surface they are either coloured as above, or are indistinctly marked. One species (*Colenis dido*) is of a most beautiful green, with black markings above, and brown and silvery markings below. *Dione juno* resembles the genus *Colenis* in shape, but most of the species of the former genus have much shorter and broader wings. They are rich fulvous, spotted or veined with black, and the hind wings and the tips of the fore wings are literally covered with large silvery spots beneath.

The East Indian genus *Cethosia* includes a number of closely-allied and very similar species, which may be distinguished at once from any other Butterflies by their elegant festooned black and white markings, especially on the under surface of the hind wings. They somewhat resemble *Danaina*, being tawny above, with black, white-spotted borders, and some species appear to mimic *Danaüs chrysippus*, &c.

The true Fritillaries are well known to all collectors of Butterflies. The genus *Argynnis* is well represented throughout the Northern Hemisphere, but there are none in Africa, beyond the Mediterranean district, nor in South America, except one or two small species in the Andes or in Chili. There are six beautiful species in England, all fulvous, with black spots and streaks above, and more or less spotted or streaked with silver on the under surface. In the North Chinese *A. sagana* the male

resembles *A. papia*, while the female is olive-green marked with white, and might well be supposed to be allied to *Apatura* or *Limenitis*. A new genus was actually formed for its reception when it was first discovered. Among the most striking of the North American species are *A. diana*, with a black male, broadly edged with orange, and a green female, spotted with whitish, and *A. idalia*, one of the largest Butterflies of the genus, which has reddish fore wings, and blackish hind wings, with two rows of whitish spots above. The caterpillars of *Argynnis* are spiny, and mostly feed on different kinds of violets.

Melitæa is another genus of small Fritillaries, of which we have three representatives in Great Britain. They are tawny, with black lines and spots above, and the under side of the hind wings is more or less banded or chequered with yellowish or reddish, being marked with black lines, and sometimes spots. The British species are local, though common where they occur. Several others are found on the Continent, two of which are black with white markings; but the greatest variety and the largest known species of *Melitæa* are to be met with in California. Many of these are black, with transverse rows of yellowish spots, sometimes alternating with reddish ones.

The European species of *Vanessa*, &c., are less numerous than the Fritillaries, but present a much greater variety of colour and markings. Their larvæ are spiny, and feed on nettles, thistles, elms, willows, &c. The smallest species of this group, though common on the Continent in damp woods, is not British. This is *Araschnia prostra*, a Butterfly which exhibits the phenomenon known as "seasonal dimorphism" in its



TRANSFORMATIONS OF QUEEN OF SPAIN FRITILLARY (*Argynnis lathonia*).

greatest perfection. It expands less than an inch and a half. The hind margins of the fore wings have two slight projections, and the hind wings have one projection in the middle, making the outer margin nearly rectangular. The spiny black caterpillar, which is sometimes striped with brown, lives gregariously on nettles. The spring brood of the Butterfly is found in April and May. It is fulvous, spotted with black. There are three white spots near the tip of the fore wings, and rows of black spots across all the wings. The under surface is brownish-red, varied with violet and pale yellow, with pale yellow veins and transverse lines. But the summer brood of the same Butterfly, which is met with in July and August, is utterly different, and until the specific identity of the two was proved by breeding and observation, it was naturally supposed to be a totally distinct species. It is black, with a red marginal line, and a white transverse band, which is interrupted on the fore wings. The under side is redder than in the spring brood, with white instead of yellow markings. Intermediate varieties are occasionally met with. This Butterfly is called "the Map" in France and Germany, probably in allusion to the character of the markings on the under surface of the wings.

The Comma Butterfly (*Vanessa C-album*) has strongly dentated wings, more so than any other British Butterfly, giving it at first sight the appearance of being very tattered. It is of a deep fulvous, with dark brown spots and borders. The under surface is brown, black, greyish, or greenish, but the hind wings are always marked with a white C beneath. There is only one other species of

this section of the genus in Europe, but in North America there are several, all very similar to the insect we have just described. Although local, the Comma is not unfrequently met with in many parts of England, but it is the least common of the British species of *Vanessa*, except the large chocolate-coloured, yellowish-bordered Camberwell Beauty (*Vanessa antiopa*), which, although abundant in America, as well as in many parts of Europe, is a great rarity in England, but like many other Butterflies is met with much more frequently in some years than in others.



COMMA BUTTERFLY.

The elegant brick-red, or pale salmon-coloured Painted Lady Butterfly (*Pyrameis cardui*), is the last European species of this group which we shall notice. The caterpillar feeds on thistle, and the Butterfly is generally common in waste places at the end of summer, not in England only, but over a great part of the world. It is much commoner in some years than in others, and is occasionally sufficiently numerous to migrate in vast swarms from one district to another.

Among the commonest and most widely distributed of the exotic Butterflies allied to *Vanessa* are those of the genus *Junonia*. As now restricted, it includes several species with smooth eyes (those of the *Vanessa* are hairy), and with slightly dentated wings. They are insects about the size of the *Vanessa urticae*, and the wings are black, brown, or grey, generally adorned with two eyes on the hind wings, and one towards the hinder angle of the fore wings. Several species are common in every collection of insects from the East Indies. *J. laomedea* is of a slightly iridescent grey, with transverse zigzag brownish lines, and a row of rather small eyes beyond the middle, of which two towards the tip, and one towards the hinder angle of each wing, are more distinct than the others, and consist of an outer brown ring, an inner grey or buff one, and a black pupil surrounded



CAMBERWELL BEAUTY.



SMALL TORTOISESHELL BUTTERFLY.

with orange. Although the East Indies form the head-quarters of the genus *Junonia*, several species closely allied to the Indian ones are met with in Africa and America.

The genus *Precis*, formerly included in *Junonia*, comprises many beautiful African Butterflies, and one or two Indian species also. The wings are generally dentated, the fore wings more or less angulated, and occasionally almost hooked, and the hind wings often produced at the anal angle. Instead of large eyes on the wings, as in *Junonia*, there is sometimes a marginal row of small ones on the hind wings. The beautiful blue *P. rhadama* of Madagascar, however, has eyes placed as in *Junonia*. The species of *Precis* are generally brown, sometimes almost without paler markings, but more frequently banded with some shade of fulvous, and occasionally with blue or red.

The genus *Kallima* is one of the most remarkable of the *Nymphalina*, from the extraordinary resemblance of the under surface of the insect to a dead leaf. The Indian species are nearly four inches in expanse, bluish or purplish above, with a small transparent spot in the middle

of the fore wings, beyond which a broad orange band in some species, or a bluish-white one in others, runs obliquely from the middle of the costa, or front edge of the fore wings, nearly to the hinder angle. The fore wings are more or less pointed, and the anal angle of the hind wings is produced into a short blunt tail. The under surface is brown, with a dark streak resembling a mid-rib running from the tip of the fore wings to the tail of the hind wings. The surface is irregularly streaked and mottled, and Mr. A. R. Wallace describes the Sumatran *Kallima paralekta* as being invisible when at rest, from its resemblance to the dead leaves among which it always perches. The Butterfly sits with its wings over its back, and its head and antennæ raised and hidden between them, while the tails of the hind wings rest upon the branch, corresponding exactly in appearance with the stalk of the leaf.

The genus *Eunica* contains a number of moderate-sized species. They are nearly all Tropical American Butterflies, of a brown or velvety black colour, and are often more or less suffused with blue, purple, or violet. One

species (*E. margarita*) is silvery white above, with the tip black, spotted with white, and a double row of dark spots on the borders of the hind wings. The outline of the wings in *Eunica* is very various, but is generally dentated, and the tip of the fore wings is often truncated. The under side of the hind wings is always marked with a row of eyes beyond the middle, but this varies very much in distinctness.

The South American genus *Catonephele* is very remarkable for the great difference between the sexes, for the females are so unlike the males that they were not only regarded as different species, but were even placed in different genera for many years. Thus the male of *C. obrius* is black,

with a broad blue band across the fore wings, and a broad orange band across the hind wings. The female is brown, with an additional blue spot near the tip of the fore wings, and one or two red spots, bordered with black, towards the base. The hind wings have three obscure narrow black stripes, the outermost sometimes marked with one or two blue spots.

The handsomest of the smaller South American *Nymphalinae* are probably those belonging to the genus *Catagramma* and its allies. The first of these is the genus *Callicore*. The species are all of a rich dark brown or black above, and the fore wings, which are often suffused with purple towards the base, are crossed by a bar of changeable bluish-green, blue, or purple. The hind wings are generally bordered by a metallic green or blue stripe. The under surface of the fore wings is of a rich scarlet towards the base, followed by a curved black band, varying in breadth, and the tip is silvery white, or buff, intersected by a black line. The hind wings are silvery white or buff, with two oval black rings in the centre, each of which contains two black spots, varying in size, and sometimes connected. These are enclosed by two large black rings, which run round the whole wing, except on the costa, where the circle is not complete.



LEAF-BUTTERFLY OF INDIA (*Kallima inachis*).

The genus *Perisama* much resembles *Callicore* in size and shape, but the band of the fore wings is frequently incomplete, and combined with more distinct basal stripes. The fore wings are black beneath, generally spotted with blue, with the tip pale, and intersected by a black line, and the basal portion is frequently more or less broadly red or yellow. The under side of the hind wings is yellow, silvery white, or buff, and is nearly always crossed by two black lines, widest apart in the middle, between which runs a row of black dots.

The genus *Catagramma* resembles the last two genera, but the eyes are naked instead of hairy. There are a great number of species, differing very much in colour and markings, and the name alludes to the elegant markings of the under surface, meaning "written beneath." These Butterflies are of a deep black, adorned with rich shades of crimson or orange on the upper side, and are frequently glossed with purple over the black, and sometimes over the crimson. In some species the sexes differ little; in others, the males are crimson and the females orange, or even, occasionally, black above. But the sexes differ much in their habits. The females generally live a retired life in the forests, and are often very rare, even when the males are abundant. There are a great number of species, all with a strong family likeness, though more varied in colour above and in patterns below than either of the two preceding genera. The pattern of the under side of the hind wings varies very much in different species. Sometimes they may be striped with black and yellow, or the centre may be black with an irregular row of blue spots, or the centre may be yellow, enclosing two large black spots, each marked with a variable number of eyes.

Callithea, the most splendid genus of the *Catagramma* group, contains larger species, found towards the west of South America. In *C. sapphira* the male is of the richest blue, while the female is blue only at the base, followed by a broad transverse orange band in the fore wings, while the hind wings are bordered with dull green. Some of the other species are similarly marked, while others are bluish-black towards the base; and a pale bluish band runs round the borders of all the wings. The under side of all the species is green, sometimes more or less broadly orange at the base, and marked with transverse rows of black spots or lines.

Batesia hypochlora, and its allies or varieties, are also large and splendid insects, from the Upper Amazons and Ecuador. The fore wings are black, with the basal third blue, and a very large red oval transverse spot or band running nearly across them. The hind wings are blue above, with a rather narrow black band near the border; and beneath they are olive-yellow, or greenish.

The genus *Ageronia* contains many common and well-known insects from Tropical America. These Butterflies frequent forests, and their habits were studied by Mr. Darwin. He met with *A. feronia* in the orange groves of Brazil, and describes it as a high flyer, but fond of alighting on the trunks of trees with its head downwards. It is remarkable for using its legs for running, but still more so for the clicking or crackling sound produced by the wings during flight. Mr. Darwin's observations have been subsequently verified by other naturalists, and the stridulation proves to be common to both sexes. It has not yet been ascertained whether the sound is produced at rest as well as when flying. Although several other Butterflies are now known to stridulate, yet this species is interesting as being the first on which this observation was made.

The species of *Ageronia* expand from two to three inches. *A. feronia* and its allies are mottled with black, bluish, and white, and are sometimes marked with dull reddish spots; and there is generally a submarginal row of black eyes with white pupils on the hind wings. Other species are velvety-black above, spotted with blue, or very deep blue, spotted with paler, and with an oblique white band in the fore wings in the females. The under surface of the hind wings may be pale silvery-grey, with a row of submarginal brown rings, bordered on each side with a brown line, or may be yellow, red, brown, or steel-blue spotted with red, in various species.

Cyrestis includes several delicate Butterflies confined to Tropical Asia and Africa. The hind wings are generally produced into a lobe at the anal angle, and there is a short projection or tail at the lower part of the hind margin, where the wing is angulated. Some of the species are white, marked with transverse dark or yellow lines towards the base; others are tawny, with dark lines, or dark brown, with a transverse band of white.

Cyrestis is represented in South America by the genus *Megalura*, which is remarkable for the superficial resemblance which the species bear to the true *Papilioninae*, or Swallow-tailed Butterflies,

from which, however, they may be at once distinguished by their imperfectly developed front legs. They are brown, tawny, or yellowish-white, marked with slender transverse lines, most conspicuous on the under side, which is generally of a paler colour. There is a lobe at the anal angle of the hind wings, and a long tail at the lower part of the hind margin. There is another group with much longer wings, somewhat resembling the tawny species of *Colenis* in colour, size, and shape, except that there are three tails on the hind wings, that in the middle being the longest.

We have already spoken of *Hypolimnas misippus*, and the extraordinary resemblance of the female to *Danaus chrysippus*. Several of the smaller species of *Hypolimnas* resemble the genus *Euploea*, but others are among the largest and handsomest of the Butterflies inhabiting Asia and Africa. One of the commonest African species is *H. salmacis*, which averages four inches in expanse. It is a dark brown Butterfly, broadly banded with white and blue. An African genus allied to this is called *Pseudacraea*, from the great similarity of several of the species included in it to those of the genus *Acraea*.

The White Admiral (*Limenitis silybilla*) is a black Butterfly with white markings, and is considered a rather scarce insect in England. Its elegant sailing flight has long been celebrated; and Haworth tells a story of an old entomologist who was too infirm to chase Butterflies any longer, but who would sit for hours together on a stile which commanded a view of a spot much frequented by this Butterfly, for the pleasure of watching its graceful evolutions on the wing. There is another European species of *Limenitis* (*L. camilla*), which is more sharply marked than the English, and is of a bluish-black. It appears rather later in the summer, and I have generally met with it flying round detached bushes, rather than in woods. The larvæ of both these Butterflies feed on honeysuckle. Many handsome species of *Limenitis*, differing very much from the English, and generally much larger, are found in India and North America.

Neptis and *Athyma* are genera closely allied to *Limenitis*. The species are very numerous in the East Indies, but a few are African, and two species of *Neptis* are European. They are dark brown Butterflies, with a white streak, often divided into two or three, running from the base of the fore wings. Rather beyond the middle of the fore wings is a transverse white band, more or less divided into spots, and more widely interrupted in the middle of the fore wings. Towards the margins is an outer row of smaller white markings. This general description will apply to almost all the species, except that the white markings are often replaced with tawny.



WHITE ADMIRAL.

Hamamimida daedalus is a common African Butterfly, not remarkable for its beauty, but curious for its resemblance in colour to a Guinea-fowl, being grey, with several rows of white spots, edged with black. The under surface is more yellowish, but varies a good deal in intensity of colour. The obscure colouring of this insect must make it very inconspicuous, especially as the variations are said to correspond to the colour of the soil in the district where it occurs.

The splendid genus *Apatura* includes the Purple Emperor (*A. iris*), one of the finest of the



A



B

A, ACRÆA GEA; B, PSEUDACRÆA HIRCE.

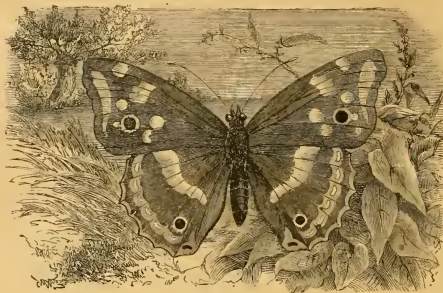
British Butterflies. It measures from two to more than three inches in expanse, and is of a dark brown above, spotted and barred with white, and there is a red ring near the anal angle of the hind wings. In the nearly allied Continental *A. ilia* there is a similar eye on the fore wings as well. The

male is shot with rich purple, and is remarkable for his lofty flight, usually perching on the tops of the tallest trees. It is common in Central Europe, but is confined to the south-east of England. Although ordinarily very difficult to capture, it will sometimes descend to the ground to drink at a puddle, or may be attracted by carrion. The caterpillar, which feeds on sallow, is green, with two horns on the head.

Aganisthos odius is a grand South American Butterfly, measuring five inches across the wings. The fore wings are long, and almost

hooked at the tip, and the body is unusually stout. The wings are of a rich black, with the basal third of the fore wings tawny, this colour projecting in a large, slightly-curving lobe, almost to the hind margin. It is a Butterfly of very powerful flight, and that of *Prepona*, an allied South American genus, is said to be so rapid that the eye can scarcely follow it. Sometimes these Butterflies perch suddenly on the trunks of trees, closing their wings and remaining immovable. But if alarmed they dart away for a moment, and then return suddenly to the same spot. These Butterflies are similar in shape to the Purple Emperor, but much larger, and with much stouter bodies. They are black, with a broad bluish-green band across both wings, which is divided, contracted, and turned inwards towards the tip of the fore wings. The upper side of most of the species of *Prepona* is similar to this, the under side is brown or grey. Near to this genus, and almost as large, measuring over three inches in expanse, is another South American genus (*Agrias*), which resembles a gigantic *Catagramma* in appearance. *A. ædon* is brown, with a broad transverse scarlet band across the fore wings, and a large blue blotch near the anal angle of the hind wings. *A. phalcidon* is dark blue, broadly bordered with green.

Charaxes is a genus almost confined to Asia and Africa, though one species (*C. jasius*), which feeds on the arbutus, is found all round the shores of the Mediterranean. It is a large Butterfly, expanding about three inches. The body is stout, the border of the fore wings is deeply excavated, and the hind wings are dentated, with two rather long tails. It is of a dark brown above, bordered with deep orange; and the under side is red, banded with white and orange, and marked with black spots, edged with white. It is a Butterfly of very powerful and rapid flight, turning about like a Swallow to avoid any obstacle. It is very shy, and delights in the hottest localities, avoiding the shade of deep woods, and preferring dry hills or the dry beds of torrents, up and down which it courses without stopping to rest. But like other



APATURA ILIA.



CHARAXES JASIU.

Nymphalinae, it has a great preference for the same spot or twig, to which it will return day after day. It is fond of strongly-smelling substances, and rotten cheese is sometimes employed as a bait to attract it.

Protophonus, the last genus of *Nymphalinae* which we shall notice, is South American. It is remarkable for its colouring, which resembles that of some of the *Heliconinae*, as well as for its peculiar shape, which is unlike that of any other insect. *P. hippona* measures about four inches across the fore wings, which are much longer than the hind wings. They are black, with a large tawny blotch running from the base to the middle, and widest on its lower side. Beyond this is an irregular transverse yellow band, and nearer the tip a white spot. The hind wings are tawny, and their lower border is black, with a row of long white spots. The long fore wings are strongly arched, curving over to the tip, which is pointed, but not long, and followed by a concavity, below which is a longer and sharper projection; and another concavity brings us round to the hinder angle of the fore wings. At the outer angle of the hind wings is a long linear tail.

FAMILY II.—ERYCINIDÆ.

This family is intermediate between the *Nymphalidae* and the *Lycanidae*, for while the front legs are perfect in the females, they are rudimentary in the males. It is divided into four sub-families, of which the first, the *Libytheinae*, containing only one genus and a very few species, has much resemblance to the *Nymphalinae*, but may be distinguished from almost all other Butterflies by the enormous length of the palpi, which are four times as long as the head, and are contiguous throughout their whole length, forming a kind of beak, as in the *Crambidae*. The fore wings have an angular projection below the tip, and the hind wings are dentated. One species is found in South Europe, which is brown, with a fulvous basal streak and large fulvous blotches. It measures about an inch and three-quarters across the wings. Several other species closely resembling this are met with in Asia, Africa, and America, and a blue species is found in the Moluccas. The pupa is suspended by the tail, as in the *Nymphalidae*. The three other sub-families, forming the *Erycinidae* proper, have very short palpi, and their pupæ are attached by the tail, and by a silken belt round the body as well. Very few species are met with out of South America, where they are exceedingly numerous, and are insects of rather delicate texture, unfitted for strong and sustained flight, and fond of settling on leaves rather than on flowers.

The second sub-family—or the first of the true *Erycinidae*—is that of the *Nemeobiinae*, and is distinguished by the subcostal nervure of the fore wings dividing into four branches instead of three. To this group belongs the British Duke of Burgundy Fritillary (*Nemeobius lucina*), which has a superficial resemblance to a small *Melitæa*. It is a local insect in the South of England, and measures about an inch across the wings, which are brown, and marked with rows of dull orange spots. On the under surface it is reddish-brown, with black marginal dots, and two rows of whitish spots on the hind wings. The East Indian species of *Nemeobiinae* are larger and handsomer Butterflies, and the hind wings are either rounded and dentated, or end in a lobe, or short, blunt tail, or are square, with a projection at the outer angle. They are generally streaked or spotted with white on the under surface. The principal South American genus of this section is *Mcsosemia*, to which belong a great number of little brown or blue Butterflies, marked with black lines, especially on the hind wings, and nearly all have a large round black spot in the middle of the fore wings, marked with two or more white dots.

The *Euselasiinae* only include one genus of importance (*Euselasia*). Their neuration is irregular, but the discoidal nervure is so closely united to the subcostal nervure that it appears to be an additional branch, or a continuation of the subcostal itself. This is difficult to explain in words, but the Butterflies themselves may be easily known, having rather short fore wings and long hind wings, often marked with lines or eyes on the under side. Some are brown, some blue, and others again are fulvous, and several species strongly resemble the small South American *Satyrinae* of the genus *Euptychia*.

The last sub-family, the *Lemoniinae*, contains species with only three branches to the subcostal nervure, and with the subcostal and discoidal nervures completely distinct. We need notice only a few of the principal genera. The species of *Limnas* have rather long fore wings, often with crimson

spots at the base. They are generally black, with orange borders or markings. The species of *Necyria* and *Ancylyrtis* are among the most beautiful of the group. They are black, with red or blue stripes, and the hind wings are often prolonged into a lobe, or a short tail. They are comparatively large Butterflies, expanding nearly two inches across the wings. *Zeonia* includes smaller Butterflies, with transparent wings, the black veins and borders excepted. The hind wings are marked with red, and terminate in a long narrow tail. *Helicopsis* includes some very delicate cream-coloured Butterflies, with three tails on the hind wings. They are varied with black or yellow above, and the under surface of the hind wings is spangled with metallic golden spots, as is also the case with several species of allied genera.

The species of *Emesis* are mostly very dull, dark brown Butterflies, with darker transverse lines, and the fore wings slightly pointed. The under surface is lighter, being dull brownish-yellow, or ochreous. *Mesene* includes a number of small red Butterflies, not expanding more than an inch across the wings, generally with black borders, or black markings on the costa of the fore wings.

A very characteristic and easily recognisable genus is *Nymphidium*, the species of which are nearly all white, with the costa of the fore wings and all the borders more or less broadly brown, and frequently marked with red lines or spots on the borders. Several long-winged genera have very little resemblance to the group to which they belong, but are more like species of *Ithomia*, or the allied genera. Such are some of the species of *Stalactis*, *Ithomiola*, &c., while *Chamaelimnas* includes a number of Butterflies with a lemon-yellow basal stripe, and a transverse band of the same colour near the tip of the black fore wings, and the hind wings are yellow, with black borders. These closely resemble an extensive group of day-flying Moths, also South American, both in shape, size, colour, and markings.

Passing on from this large group of delicately-marked, but rather uninteresting Butterflies, we come to another extensive and more familiar family of small Butterflies.

FAMILY III.—LYCÆNIDÆ.

In this family we find the legs of the males nearly as well developed as those of the females, except that they are rather smaller, and the last joint of the tarsi terminates in a simple hook. Their larvae are short and stout, somewhat resembling a Woodlouse in shape.

The great majority of these Butterflies are of small size, the largest seldom expanding more than an inch and a half or two inches, and the prevailing colours are blue, copper-red, or brown. The under surface is generally marked either with black eyes enclosed in pale rings, or with pale transverse lines; and the hind wings frequently end in a short and slender tail. This family is well represented in all parts of the world, especially in the Northern Hemisphere and in South America; but the number of distinctly defined genera is small, although the species are very numerous.

Miletus symethus is a small brown Butterfly, with a white spot on the fore wings, and a grey under surface, marked with obscure lines. It is common in the East Indies, and its legs are unusually



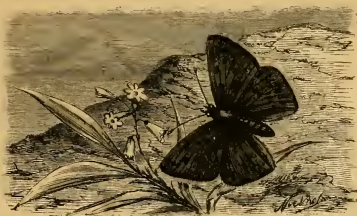
LYCÆNA PHLÆAS.

stout; but what is much more remarkable is that it is said to inhabit Ants' nests. Strange as this habit is, it is by no means unexampled, for it is well known that a great variety of insects do inhabit Ants' nests, and among them is a small Scottish Moth (*Tinea ochraceella*), belonging to the same genus as the Clothes' Moths.

The species of *Zeritis* are red, with brown borders, and with metallic spots on the under surface of the hind wings. They are found in Africa, but do not equal the splendid colouring of the European Copper Butterflies of the genus *Lycaena*. The Small Copper (*L. phlaeas*) has bright coppery-red fore wings, with black spots and borders, and the hind

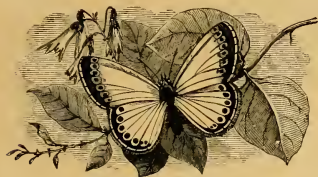
wings are black, with a marginal copper band. It abounds almost everywhere in dry, sunny, flowery places, and is found throughout Europe, North Africa, Northern and Western Asia, and a great part of North America. It is a pugnacious little Butterfly, often attacking and driving away much larger insects, if they approach the flower on which it is resting. The caterpillar is green, with red lines on the back and sides, and feeds on sorrel.

Another species (*Lycena dispar*, the Large Copper) used to be common in the fens of the Eastern Counties of England. It expands about two inches, and the male is brilliant copper, with rather narrow black borders, and two spots in the discoidal cell of the fore wings. The female has copper-coloured fore wings, with three discoidal spots, and an outer row of large black spots. The hind wings are dark brown, with black spots, and a submarginal copper band, and are bluish-grey beneath. The caterpillar used to feed on the great water-dock, but the insect has not been seen alive in any stage for some thirty-five years, and is believed to have become quite extinct in consequence of the draining of the fens. *L. dispar* is the largest species of the genus; yet the males of some others surpass it in the brilliancy of their colouring, and in some instances the copper is strongly glossed with blue or purple, as, in *L. gordius*, for example. But these species are not British, though common in some parts of the Continent.



LYCENA GORDIUS.

The small blue Butterflies, so familiar to all residents in the country, belong to the genus *Polyommatus*,* so called from the majority of the species being decorated with numerous "eyes," or black spots in white rings, on the under surface of the wings. In most of the species the males are blue and the females brown, but in some cases both sexes are brown, and some few species white. But there are no white species in England, nor is there (except *P. baticus*, as an occasional visitor) any representative of the section of the genus in which the hind wings are furnished with a short tail. The Common Blue (*Polyommatus icarus*) is a Butterfly about the size of the Small Copper, and of very similar habits. The male is lilac blue, with white fringes, and the female is blue or brown, with a marginal row of red spots. The under surface is brownish-grey on the fore wings, and yellowish-brown on the hind wings, with a marginal row of red spots, bordered with black ones, and a central row of eyes. There are also two or three spots nearer the base both on the fore and hind wings.



POLYOMMATUS CORYDON.

In the Clifton Blue (*Polyommatus adonis*) and the Chalk-hill Blue (*P. corydon*) the fringes of the wings are spotted with black. The males of these insects are bright sky-blue and pale-blue respectively, and, like most of the British species of the genus, they are common on the chalk in the South of England. The Azure Blue (*P. argiolus*) is found in woods, flying about holly trees, but is not common everywhere. The male resembles the Common Blue above; the female is blue, with broad brown borders to the fore wings. The under surface is pale blue, with a central row of small

black spots. The Silver-studded Blue (*P. argon*) is common on heaths, and much resembles the Common Blue, but the outermost of three rows of black eyes on the under side of the hind wings is conspicuously dusted with bright metallic blue. Throughout this group of Butterflies the species are best to be distinguished by the colour and markings of the under side of the hind wings. In some Continental species, the upper side of which differs little from that of English species, the hind wings are green beneath, or brown with large white spots. The caterpillars of these Butterflies generally feed on vetches, trefoil, and similar plants, and a singular discovery has been made respecting them in America. They exude a liquid from their bodies of which Ants are very fond, and these attend upon them for the sake of it as they do upon the *Aphides*. This

* Many-eyed.

is an indirect confirmation of the statement which we have already mentioned, that *Miletus symethus* is found in Ants' nests.

The genus *Hypochrysois*, which is confined to Australia and the Malay Archipelago, contains blue or orange Butterflies, rather larger than the species of *Polyommatus*. The hind wings are dentated, but are chiefly remarkable for the gaudy colouring of the under surface, which is red in some species, with yellow and silvery spots, while it is banded with green and brown, or red, green, and yellow, and intersected with silvery lines, in others.

The genus *Thecla*, which includes the Butterflies known as Hair-streaks, except the group to which the Brown and Purple Hair-streaks belong, is the largest in the family. There are probably six hundred species known at present, but it is likely that they will ultimately be divided into smaller genera. *Polyommatus* is not quite so large a genus, but is more compact.

These Butterflies are exceedingly numerous in tropical America, but are poorly represented in other parts of the world, and are not found at all in Africa (except on the Mediterranean coast) nor in Australia, where they are replaced by other genera. They are generally rather small Butterflies, of a blue or brown colour above, and with a short tail on the hind wings. The under surface is brown, grey, or white, and often marked with pale lines, whence the Butterflies derive their name of Hair-streaks. There is often an orange spot above or below at the anal angle of the hind wings. The White Letter Hair-streak (*Thecla W album*), a rather uncommon species in England, is brown above, and the under surface is paler, and marked with a very distinct white line across all the wings, forming a large W at the anal angle of the hind wings. Nearer the margin of the hind wings beneath is an orange band. Like most of the other species of the genus, this Butterfly may be looked for in woods, and its larva feeds on the elm. The Green Hair-streak (*T. rubi*) is a commoner



GREEN HAIR-STREAK.

insect, found in open woods and heaths in spring and early summer, flying about, and settling upon brambles. It differs from the other European Hair-streaks by wanting the tail on the hind wings, and by the bright green colour of the under surface. On the upper side it is uniform brown. There are several South American species allied to this, which are blue above. The South American Butterflies of this genus present a great variety of colour and pattern on the under surface, but eye-spots, which are almost universal in *Polyommatus*, are seldom to be met with in *Thecla*. Some species resemble *Satyrine*, being streaked below in such a manner as to resemble Butterflies of the genus *Euptychia*. Some of the largest species expand about two inches across the wings, and are most beautifully coloured on the under surface. Several of these have two tails to the hind wings, and are gorgeously spangled with golden green beneath, and are sometimes varied with reddish or purplish markings. *Thecla marsyas*, on the other hand, is of a greenish-blue above, with the costa and tip of the fore wings black,

and the under surface is very pale shining violet-grey, marked with black spots bordered with white.

The species of *Thecla* have only ten nervures on the fore wings, but those of the next genus (*Zephyrus*) have eleven, the subcostal nervure emitting two branches before the extremity of the discoidal cell, and a third, which bifurcates, beyond. In *Thecla*, three simple nervures are emitted before the end of the cell, and none beyond. The *Zephyri* are not numerous, and are all found in Europe or Asia, except one species, which is Californian. The Purple Hair-Streak (*Z. quercus*) is common in oak woods. The male is purplish-blue, with black hind margins, and the female is brown, with a rich purple blotch on the fore wings. The under side is silvery grey, with a white line towards the hind margin, and some orange and black spots towards the hinder angles of all the wings. Several of the Japanese and North Indian species of *Zephyrus* are of a beautiful brassy green on the upper side.

Most of the remaining genera of the *Lyceonide* are found in Asia or Africa, and are blue, brown, or white above, and adorned with one or two tails on each hind wing. These are generally very delicate and easily broken off, and are sometimes of very great length, equalling or exceeding the total length of the wings themselves.

One of the commonest genera in the Eastern Archipelago is *Amblypodia*. These are blue Butterflies, often with brown borders, resembling the European species of *Thecla* in shape, and, like them, generally with a short tail on the hind wings. But they are much larger, many of the species measuring two inches across the wings. The under surface is brown, with darker bands and markings, bordered with pale lines.

Finally, *Eumecurus* is a small South American genus, containing a few dark brown Butterflies, more or less marked with green on the upper side. The hind wings are bordered by a green band, and on the under side by three nearly contiguous rows of spots of the same colour.

FAMILY IV.—PAPILIONIDÆ.

The *Papilionidæ* may be at once distinguished from all other Butterflies (except the *Hesperiidæ*, which we need not now consider) by their possessing six perfectly-developed legs in both sexes. The pupa, or chrysalis, is not only attached by the tail, but is generally fixed in an upright position by a belt of silk round the body. There are two sub-families. In the first (the *Pierinæ*) the inner margin of the hind wings is not concave, and the larvæ are slender, and covered with fine hair. In the second sub-family (the *Papilioninæ*) the inner margin of the hind wings is concave, and the larvæ have always a retractile fork on the neck.

The *Pierinæ*, to which many of our commonest Butterflies belong, are, with few exceptions, white or yellow, with black spots and borders. They are Butterflies of about the middle size, seldom measuring less than an inch and a half, or more than three inches across the wings, and the wings are very rarely dentated, and though furnished occasionally with angular projections in the middle, or towards the anal angle of the hind wings, are never tailed, in the strict sense of the term.

The more aberrant genera are South American, and sometimes resemble other Butterflies, but the first (*Perente*) stands quite by itself. These are black Butterflies, measuring nearly three inches across the rather broad wings, and most species have a transverse red bar across the fore wings. Many of the species of *Archonius* resemble some of the smaller *Nymphalidæ*, being black or brown, with a yellow or white band, often broken into spots, running across the middle of both pairs of wings. The hind wings are often more or less dentated, and are frequently ornamented beneath with numerous yellow spots and festooned markings of brown, black, and white.

The genus *Dismorphia* is likewise South American. It includes a number of long-winged Butterflies with narrow wings, which have no resemblance to the family to which they belong, but "mimic" various species of *Danainæ*. Many are black and yellow, others are marked with red, and some are even transparent, with black bands and borders. Most species can readily be distinguished from the Butterflies which they resemble by their very broad hind wings, but in some instances they are so much like the long-winged *Danainæ* that they might readily be passed over for them, but for the structure of their legs.



A, *DISMORPHIA ORISE*; B, *METHONA PSIDII*.

many of the species measuring nearly three inches across the rather broad wings, and most species have a transverse red bar across the fore wings. Many of the species of *Archonius* resemble some of the smaller *Nymphalidæ*, being black or brown, with a yellow or white band, often broken into spots, running across the middle of both pairs of wings. The hind wings are often more or less dentated, and are frequently ornamented beneath with numerous yellow spots and festooned markings of brown, black, and white.

Most of the small white and yellow Butterflies of the Tropics belong to the genus *Eurema*. Many of them measure an inch, or under, across the wings, and few expand as much as two inches. They are never spotted, but the wings are more or less broadly bordered with black; and in some of the larger South American species the hind wings project below in an acute angle.

The genus *Pieris* includes the White Cabbage Butterflies, which are too well known to need description. Their green caterpillars may often be seen feeding on cabbage, &c., and the pupæ are found on walls and palings, and are not unfrequently surrounded by the little yellow cocoons of an Ichneumon Fly (*Pimpla manifestator*). The foreign species of *Pieris*, though numerous, call for no special notice, but the East Indian species, belonging to the allied genera *Tachyris* and *Delias*, are often very beautiful. *Tachyris nero* has rather pointed fore wings, and is of a uniform red, with black nervures. On the under surface it is yellowish. Other allied species are blue, and others white, with brown borders. Most of the species of *Delias* are white, with a row of red spots along the borders of the hind wings beneath, and another East Indian genus (*Prioneris*) is remarkable for the costa of the fore wings being ridged like a saw in the males. *Perrhybris*, the last of the sections of the old genus *Pieris* which we need notice here, is found in South America, and is remarkable for the difference between the sexes. The male of *Perrhybris pyrrha* is white, with black borders above, but on the under side it is banded with white, black, and red. The female is streaked with black, yellow, and fulvous, giving it very much the appearance of one of the *Heliconine*, or of those *Danaïæ* which most resemble them. This Butterfly is very common in America, but there are several other species of the genus which exhibit a similar disparity in the sexes to a greater or less extent. The collection of the late Mr. Hewitson, now in the British Museum, contains a very singular specimen of *P. pyrrha*. It is a male, in which the right-hand wing is coloured as in the female, with the exception of one or two white spaces.

Most of the larger yellow Butterflies of the Tropics belong to the genus *Catopsilia*. They generally measure about three inches across the wings, though some are larger or smaller. The fore wings have the costa arched, and the hind margin nearly straight, and the hind wings are rounded, very slightly dentated, and occasionally obtusely pointed at the anal angle of the hind wings. The antennæ are of moderate length, and of a black colour. A few species are dull white, irrorated with brown on the under surface, but the greater number are of some shade of yellow or orange. The under surface is generally irrorated with reddish, and there is often a reddish-brown ring (frequently double) surrounding a silvery-white spot.

One of the prettiest Butterflies is the Brimstone (*Gonepteryx rhamni*), which is common in woods in most parts of England almost throughout the year. The male is sulphur-yellow, and the female whitish-yellow, and there is a small orange spot in the middle of each wing. The antennæ are short, thick, and of a reddish colour, and the body is black, clothed with long white hair. The Butterfly hibernates, and appears very early in spring; the green caterpillar feeds on buckthorn. An allied species (*G. cleopatra*) is common in South Europe, in which the fore wings are orange in the male, and there are one or two species of *Gonepteryx* in tropical America which are remarkably similar to *G. rhamni*, but are double the size.

The Clouded Yellow Butterflies of the genus *Colias* are found in every quarter of the globe, but in the tropics are only to be met with in the mountains. They are most numerous in temperate climates, and are Butterflies of moderate size, averaging about an inch and a half in expanse. The wings are moderately broad and more or less rounded, and are always of an orange or yellow colour, with a black border varying in width, which is generally lined with yellow in the male, and spotted with yellow in the female. There is a black spot in the middle of each fore wing, and there is often a single or double silvery spot surrounded with darker on the under side of the hind wings, as in *Catopsilia*. The caterpillars feed on clover and other leguminous plants, and the Butterflies are commoner in some years than in others, and are most frequently met with in autumn. Our commonest species, the Clouded Yellow (*Colias edusa*), is of a bright orange-yellow, with black borders, and is swifter on the wing than almost any other species. It flies low, but with such rapidity that it is very difficult to run down, though when not alarmed it will often settle on a flower, when it is easily captured. Some of the foreign species allied to this have a pink or purple flush over the orange,

which is occasionally visible in very fine specimens of *C. edusa*. And this species, as well as all the other orange species of *Colias* known, has two varieties of the female, one orange, and another—much scarcer—of a whitish colour. The Pale Clouded Yellow (*C. hyale*) is of a pale yellow colour, with narrower borders, and is a much scarcer insect than *C. edusa* in England, though more abundant on the Continent.

The Orange Tip (*Euchloe cardamines*) is a very pretty spring Butterfly, found in woods and meadows in April and May. It is white, with a black spot at the end of the cell of the fore wings, which are likewise tipped with dusky, and there is a large orange blotch filling up the whole space between, in the male only. The under surface of the hind wings and of the tip of the fore wings is chequered with green and white. It is an insect of weak flight, and very easily captured, but it is fond of settling with its wings closed on the flowers of umbelliferous plants—as observed by the late Mr. T. W. Wood—and as the colour of the under surface of the Butterfly is very similar to that of the plant, it is reasonable to suppose that it often escapes observation in this manner. The caterpillars are green, with a white stripe on each side, and feed on various cruciferous plants. The pupa is pointed at both ends, and somewhat resembles a boat in shape.

Orange Tips, belonging to the nearly allied genus *Teracolus*, are common in Africa, but most of these have either a black band on the inner margin of the fore wings, or a black border, or black marginal spots on the hind wings, and are not mottled with white and green beneath. In some species, however, the orange blotch on the fore wings is replaced by the most beautiful violet. The species of *Hebomoia* are rare insects, found in the Moluccas. One species only (*H. glaucippe*) is also common in India. It measures upwards of four inches across the wings, which are of a slightly yellowish-white. The outer portion of the fore wings is triangularly black, filled up by a broad band of connected orange spots, indented outwardly by the black border, and marked with an irregular row of small black spots in the middle.



ORANGE TIP BUTTERFLY.



ORANGE TIP BUTTERFLY AT REST.

The *Papilioninae* are in general much larger and handsomer Butterflies than the *Pierinae*. They exhibit great varieties of form and colouring, and the hind wings are generally dentated, and often tailed. The caterpillars are of various shapes, but are usually rather stout, and sometimes thicker in the middle than at the extremities. They have always a retractile fork on the segment behind the head, which is believed to be serviceable in driving away Ichneumon Flies, or other enemies.

The genus *Parnassius* more resembles the *Pierinae* than any other of this group. The Butterflies are all mountain insects, and are confined to Europe, Asia, and the west of North America. The

best known species (*Parnassius apollo*) is abundant in the Alps. It is white, thinly scaled towards the extremities of the wings, and the fore wings are marked with several black spots. On the hind wings are two large round red spots, whitish in the middle, and enclosed in black



PARNASSIUS APOLLO.

rings. Most of the other species of *Parnassius* closely resemble this; but *P. mnemosyne*, also an Alpine species, has no red spots, but only two black spots on the fore wings, and even these disappear in the Siberian *P. stubendorfi*. The few known caterpillars of this genus are black, with rows of red spots on the sides, and feed on different species of saxifrage.

The genus *Teinopalpus* is distinguished from any other of the sub-family by the unusual length of its palpi. *T. imperialis* is one of the rarest and most beautiful of Himalayan Butterflies, and measures about five inches across the wings, which are black,

dusted all over with velvety green, and banded with purple. The hind wings are very strongly dentated, with one long tail in the male, and three in the female.

The great genus *Papilio*, which includes the well-known Swallow-tail Butterflies, may be known from the other genera of the family by its longer antennæ and very short palpi. There are about 500 species known at present, but only four are European, and the genus attains its maximum of size, beauty, and variety in Africa and the Eastern Archipelago. It is in the latter region that the splendid Bird-winged Butterflies, belonging to the sub-genus *Ornithoptera*, may be found. All the species included in it are very large insects, with long fore wings, measuring from five to eight or nine inches across, and short, more or less dentated hind wings, which, however, are not tailed. The first group have velvety-black wings, with a broad green stripe running parallel to the costa, and a narrower bar running near the inner margin and curving up along the hind margin. The hind wings are green, with a row of round black spots, and the abdomen is golden-yellow. Such are the males. The females are large black Butterflies, with two rows of white spots on the fore wings, and a row of very large oval ones, marked with round black spots, near the border of the hind wings. In one species (*Ornithoptera urvilliana*), which has been brought from Duke of York Island, the ordinary green of the male is replaced by the richest blue; in another (*P. cræsus*) it has been changed for the most brilliant golden-orange. The latter species is confined to the two small islands of Batchian and Gilolo, in the Northern Moluccas, where it was discovered not many years ago by the enterprising traveller and naturalist, Mr. A. R. Wallace. After having only caught an occasional glimpse of this magnificent species flying far out of reach, he succeeded in finding a beautiful shrub with yellow flowers which was frequented by the insect; and subsequently his native collector met with it flying along the bed of a large rocky stream, and settling occasionally on stones and rocks in the water. Mr. Wallace thus describes his first capture of the insect:—"None but a naturalist can understand the intense excitement I experienced when I at length captured it. On taking it out of my net, and opening the glorious wings, my heart began to beat violently, the blood rushed to my head, and I felt much more like fainting than I have done when in apprehension of immediate death. I had a headache the rest of the day, so great was the excitement produced by what will appear to most people a very inadequate cause."*

The second group of *Ornithoptera* is not confined to the islands, but extends to India and South China. The fore wings are narrower than in the preceding group, and are black, while the hind wings are yellow or golden-yellow in the centre, with black borders, or conical marginal spots, and often a row of round black spots within them.

The third group contains but one species—another grand discovery of Mr. Wallace's—*Ornithoptera brookeana*, from Borneo and Sumatra. It is black, with a row of large green spots on the outer portion of the fore wings. They are of a long triangular form, the apices extending to the margins.

* "Malay Archipelago," ch. xxiv.

The hind wings have a broad continuous band of green across the centre. The collar is broadly red.

There is a very large and difficult group of South American *Papilios*, resembling *Ornithoptera* in form, but less than half the size, only averaging about three inches across the wings, which are black, often with a large white or green spot on the fore wings, and with a crimson band on the hind wings, which is not unfrequently glossed over with the most beautiful pale iridescent bluish or greenish violet. Another South American group resembling these has a short pointed tail on the



LEPTOCIRCUS CURIUS.

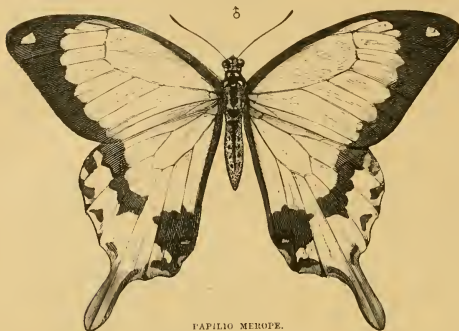
ORNITHOPTERA AMPHRYSUS.

hind wings; and a third group from the same country includes brown species of larger size, with one or two rows of ochreous yellow spots running round all the wings. The hind wings are dentated but not tailed.

Among the East Indian species there are some brown Butterflies, glossed with blue and spotted with white in the same manner as in the genus *Euplaea*, which they resemble in shape and size as well as colour. A second East Indian group is black, with a large white spot, divided by the veins on the hind wings, which are tailed; and a third section, closely resembling this, contains black species, dusted all over with golden-green. Both these groups contain species of considerable size, often measuring four inches or more across the wings. These lead us on to the splendid *Papilio ulysseus* and its allies, which are met with, like the *Ornithoptera*, in the Eastern Islands. These are large blue Butterflies, with black borders, and tails on the hind wings. Mr. Wallace describes one species as darting down in openings of the forest from the tops of the trees for a moment, and

then soaring out of sight with equal suddenness. All these large Butterflies appear to have a very lofty and powerful flight, and the difficulty of obtaining them is frequently the chief cause of their rarity in collections.

The commonest of the European Swallow-tails, and the only one found in England, is *Papilio machaon*. It is a sulphur-yellow Butterfly, with black markings, and borders to the fore wings. The hind wings are tailed, and their dark border encloses a row of large bluish spots,



and there is a large red spot at the anal angle. The caterpillar is green, with black stripes spotted with orange on the sides, and feeds on various umbelliferous plants, including the common carrot. In England this Butterfly is confined to the fenny districts in the east, but on the Continent it is quite a common species in gardens, clover-fields, and woods.

Many East Indian or African species are black, spotted or banded with green, and several of the latter feed on the orange-tree; but a far more remarkable African Butterfly is *P. merope*. The male

is a cream-coloured Butterfly, with black borders to the fore wings, marked with a pale spot near the tip. The hind wings are tailed, and marked with a more or less connected row of black spots; but the females are all tailless, and have no resemblance whatever to the male in either shape or colour, but resemble various African species of *Danaïa*. One female is black, with ochreous spots and markings; another is black, with a very broad white band across the hind wings (sometimes extending nearly to the base), and continued on the inner margin of the fore wings. There is also a broad white transverse band towards the tip of the fore wings, and several smaller white spots. Another female is similar to this, but the pale markings are deep ochreous-yellow, the hind wings being wholly of this colour, except a black border. In others, again, the fore wings are black and white, and the hind wings are of some shade of yellow, with black borders. Other species of *Papilio* are known in which the females differ equally from the males, or which are polymorphic; but this Butterfly is peculiarly remarkable, because a closely allied species occurs in Madagascar, in which the female only differs from the male by the presence of a broad black bar on the costa of the fore wings.

The genus *Leptocircus* includes a few small black, green, and transparent East Indian Butterflies, of a very peculiar shape, which will be seen in the figure on p. 51.

FAMILY V.—HESPERIIDÆ.

The *Hesperidæ*, the last family of Butterflies, although numbering at least 1,500 species, need not detain us long, as very few are found in Europe, and the foreign species call for but little remark. They are mostly small Butterflies, with thick bodies and comparatively small wings. The six legs are all fully developed in both sexes, and the head is large. The antennæ, instead of being placed close together, as in other Butterflies, are placed widely apart, and are often hooked at the tip. The caterpillars are short, tapering at both ends, and the head is large. They generally live between leaves loosely spun together, and construct a slight cocoon in the same manner. The Butterflies are called Skippers, from their short jerking flight.

The first genus (*Thymele*) is confined to tropical America, and may be known by the hind wings being produced into a rather long, broad tail. The Butterflies are brown, often greenish towards the

base, and with transparent dots or spots on the fore wings. *Telytonus* is another American genus, containing rather larger species, with a lobe instead of a tail at the anal angle of the hind wings. These are brown Butterflies, with yellowish-tawny markings. *Casyapa* is an East Indian genus, also brown, with large yellowish spots on the fore wings, but the hind wings are not produced at the anal angle. These Butterflies are among the largest of the family, measuring three inches in expanse, but they are surpassed by the African *Ismene iphis*, the giant of the *Hesperiidæ*, which sometimes measures as much as four inches across the wings. This is a black or bronzy-greenish Butterfly, with rather long fore wings and long hind wings, lobed at the anal angle; the collar and part of the head are scarlet. Other species of *Ismene*, usually of rich dark colours, but much smaller than *I. iphis*, are common in Asia and Africa. The genus *Pyrhopyga* is South American, and includes several black or blue-black species, generally with a red head and tail, and sometimes with reddish or yellowish borders. The hind wings are often slightly produced at the anal angle. They generally expand rather less than two inches, but some of the larger species are black, with their bodies striped and banded with black and white, or black and green, and their wings marked with transverse bands, some green and some transparent.

The great genus *Pamphila*, the most typical of the family, contains small species, seldom exceeding an inch and a half in expanse. Most of the species are brown, with tawny markings, and there is nearly always a black longitudinal patch of raised scales on the fore wings of the male. In many species, as in the Pearl Skipper (*P. comma*), a common Butterfly on the chalk in the South of England, the hind wings are green beneath, with white spots. The species of *Hesperia* are small Butterflies resembling the Grizzled Skipper (*H. malva*), which is common in woods in spring. It is blackish-brown, with many white spots, which form irregular bands on the fore wings, and the fringes are also spotted with black and white. Several allied species are found on the Continent.

The South American genus *Pythonides* is allied to this, and contains species of about the same size. Some of these are white, with dark borders and dark veins; others are dark brown, with bluish or transparent spots on the fore wings, and a blue band or border on the hind wings. The Dingy Skipper (*Nisoniades tages*), a dull brown butterfly, with very obscure markings, is found in England, and several of the foreign genera are also very obscurely marked. The South American *Achlyodes busirus* is a blackish Butterfly with obscure darker markings and a rather irregular outline. The hind wings are bordered with yellowish beneath.

At the end of the *Hesperiidæ* we may place a few species of doubtful position, intermediate between Butterflies and Moths. One of these (*Megothymus yuccæ*) is a rather long-winged insect, expanding nearly three inches. It is brown, with tawny markings, and is found in the Southern



A, AMAURIS NIAVIUS; B, PAPILIO MEROPE (FEMALE).

United States and Mexico, where its caterpillar lives in the stems of the American aloe. Another species (*Euschemon ruflesiae*) is an Australian insect of nearly equal size. It is of a rich velvety black, with bright yellow markings on the hind wings, and is remarkable for having the fore and hind wings connected by a bristle at the base, an arrangement frequently met with in Moths, but not occurring in any other known Butterfly.

CHAPTER XI.

MOTHS.

The Pages—The *Castniidae*—Moths with Clubbed Antennæ—Humming Bird Hawk Moth—Bee Clear-wings—Lovers of the Vine—Eyed Hawk Moth—Death's Head Hawk Moth—Scented Hawk Moths—Hornet Clear-wing—Currant Clear-wing—The Green Foresters—The Burnets—Day-flying Moths of the East Indies—The Footmen—The Tigers—The Gold-tail Moth—The Gipsy Moth—Case-bearing Moths—The Puss Moth—The Prominents—The Lobster Moth—The Processionary Caterpillars—The Silkworm—The Atlas Moth—The Ailanthus Silkworm—The Tusseh Silkworm—Long-tailed Moths—The Emperor Moth—The Lappet Moth—The Oak Eggar—The Lackey Moth—The Wood Leopard Moth—The Goat Moth—The Swifts—The Night Moths—The Wainscots—The Dark Arches—The Cabbage Moth—The Cutworms—The Yellow Underwings—The Chestnuts—The Angle Shades—The Sharks—Beautiful Yellow Underwing—The Gamma Moth, or Silver Y—The Burnished Brass Moth—The Old Lady—The Red Underwings—The Orange Moths of Australia—The Great Owl Moth—The Snout—The Loopers—The Swallow-tail Moth—The Brimstone Moth—The Thorns—The Emeralds—The Waves—Heath Moths—The Soldier Moths—The Magpie Moth—Winter Moths—The Pugs—The Carpets—*Eratina*—The Pearls—The Meal Moth—The Crimson and Gold—The China Marks—The Small Magpie—The Knot-horns—Their Webs—The Grass Moths—The Bell Moths—The Green Oak Moth—Pests of the Orchard—Jumping Seeds—Clothes' Moths—Long horns—The Smallest Moth known—The Plume Moths—The Twenty-plume Moth—Fossil Butterflies and Moths.

MOTHS are many times more numerous than Butterflies. In Britain we have about thirty Moths to every Butterfly; and although the same proportion does not hold good elsewhere (for there are only seventeen Moths to one Butterfly on the Continent), yet, taking the whole world, we are at present acquainted with about 40,000 or 50,000 Moths, and only 10,000 or 12,000 Butterflies, although comparatively little attention has yet been bestowed on Moths either by collectors or entomologists. In discussing the Moths, therefore, we must here content ourselves with briefly noticing the principal families, and a few of the more interesting species. But the classification of Moths is at present much less satisfactory than that of Butterflies, and it is not pretended that the families of Moths about to be enumerated follow in natural order. But we find throughout nature that many groups of animals and plants combine the characters of others in varying proportions, and that it is frequently impossible to arrange either families, genera, or species in a linear series which is also natural, even in the case of groups which are much better understood than the Moths. The old groups, *Sphingides* and *Bombyces*, the first of which included the families up to the *Zygonide* inclusive, and the latter the remaining families to the *Hepialide* inclusive, are now abandoned by most entomologists as scientifically accurate terms, though still frequently used for convenience in a general manner.

The *Uraniide*, or Pages, include a small number of very beautiful Moths, formerly regarded as Butterflies, and still of doubtful position. The typical genus *Urania* is South American. The species are all transversely banded with black and green, and there is a long tail, sometimes edged with white, on the hind wings. They measure about three inches across the wings, and but for the long and slender antennæ might well pass for true *Papilios*. They fly by day, and one species (*Urania fulgens*) migrates in large flocks at certain seasons across the Isthmus of Panama. Several genera allied to this, but of duller colours, are found in the East Indies, but one of the most beautiful insects known is the splendid *Chrysiridia madagascariensis*, which is banded with black and green. The hind wings are three-tailed, and a great part of their surface is of a flame-coloured red, shading into orange on the under surface, and with black markings. This insect, which measures four inches across the wings, is common in Madagascar and at Zanzibar; and it is stated that if the Moth emerges from the chrysalis in the shade the wings take much longer to develop, and are much less brilliant than when it emerges in the sunshine. These Moths are referred by some writers to the *Geometride*.

The *Castniide* are another group of day-flying Moths, common in the East Indies and America, which used to be regarded as Butterflies by early writers on entomology. They have robust bodies,

and broad wings; the antennæ are stout, and thickened gradually before the extremity, which ends in a slender hook. The South American species of *Castnia* are large Moths, measuring from two to six inches across the wings, and in many cases the fore wings are dark, and the hind wings banded with white, and spotted towards the borders with red. But they vary considerably, both in form and colour. Some few species of the family are transparent; and in the Australian genus *Synemon* the antennæ are clubbed, and the Moths, which expand about an inch and a half across the wings, might easily be mistaken for *Hesperiidae*.

We now come to the great family of *Sphingidae*, or Hawk Moths, which may be known by their large head, prominent eyes, stout antennæ, more or less thickened in the middle, and often serrated, but not pectinated, in the males, and their long, narrow, pointed wings. The caterpillars are smooth, often green, with transverse stripes on the sides, and there is nearly always a horn on the back of the last segment but one. They change to pupæ either on the surface of the ground or in a cell under ground, which they form for the purpose. Every one is familiar with the Humming Bird Hawk Moth (*Macroglossa stellatarum*), which may often be seen buzzing over the flowers in our gardens, and rifling them of their sweets by means of its long proboscis, without ever resting. It is not uncommonly mistaken for a real Humming Bird, and some of the



HUMMING BIRD HAWK
MOTH.



OLEANDER HAWK MOTHS. (*Characampa nerii*.)

allied South American species actually resemble Humming Birds so closely in flight that they cannot be distinguished from them on the wing: and during his travels on the Amazons Mr. Bates often shot one of these Moths by mistake for a Humming Bird. Our common species has brown fore wings, and reddish tawny hind wings, and the abdomen is tufted at the extremity. Most of the foreign species are very similarly coloured.

The Bee Hawk Moths (*Sesia fuciformis* and *bombyliformis*) are of about the same size and shape as the Humming Bird Hawk Moth; but their bodies are yellow, with a reddish-brown belt, and downy, and the wings are transparent, with brown or reddish-brown borders. They

are not uncommonly seen flying over flowers in woods in spring, but their flight is much less rapid than that of *M. stellatarum*. There is a beautiful Continental Hawk Moth about the same size as

these, with green fore wings and yellow hind wings, and the borders of all the wings are strongly dentated. It is called *Pterogon proserpina*, and flies at dusk.

Many of the larger *Sphinges* feed on the vine, the best known of which is the Sharp-winged Hawk Moth (*Chærocampa celerio*), which is common in many parts of Europe, Asia, and Africa, though rare in Britain. It has pale brown fore wings, with a waved silvery stripe running from near the base of the inner margin to the tip; the hind wings are rose-colour, with the hind margins and a central streak broadly black. The caterpillars of the genus to which this insect belongs have the front segments tapering and retractile, which gives them a fancied resemblance to a hog's snout or elephant's trunk, whence they derive their Greek name of *Chærocampa* (hog's snout), and their English name of Elephant Hawk Moths, generally applied to two smaller and commoner species of this genus. There is an American genus allied to these, called *Philampelus* (or vine-

loving), because most of the species feed on this plant. One of the most singular species is *Philampelus vibrusce* (the lover of the wild vine), which is common in Central and South America. The fore wings are dull green, and the hind wings are pale blue and black at the base, with broad pale yellow borders. It measures about five inches across the wings.

Our only genus of Hawk Moths with dentated wings is *Smerinthus*, to which the Eyed Hawk Moth (*S. ocellatus*) belongs. The fore wings are light brown, and the hind wings are pale pink, with a large round blue spot in a black ring towards the anal angle. One of the allied North American species (*S. geminatus*) has a double eye in a similar position.

One of the most remarkable species of this group is the Death's Head Hawk Moth (*Acherontia atropos*), the largest Moth found in Britain. The fore wings are dark brown, varied with black, grey, and

yellowish, and the hind wings are dark yellow, with two black bands. On the back of the thorax is a pattern in grey and black, not unlike a skull. The abdomen is banded with black and yellow, with a longitudinal bluish-grey band on the back. The body is very stout, the antennæ are thick and rather short, and the wings expand about six inches. The enormous yellowish-green caterpillar, with dark stripes on the sides, feeds on various plants, including the potato, and has actually been sometimes mistaken for the Colorado Potato Beetle! The Moth is capable of producing a sound resembling the squeaking of a mouse, and will sometimes enter hives to feast on the honey. It is supposed that its squeak overawes the Bees, in the same manner as the voice of their own queen. I may here mention that I once knew a German artisan who was an enthusiastic collector of Butterflies and Moths, and when he was dying he requested a friend to place a specimen of this insect on his breast in his coffin, which was accordingly done.

The type of the *Sphingideæ* is the Privet Hawk Moth (*Sphinx ligustri*). It measures about four



EYED HAWK MOTHS.



CHRYALIS OF DEATH'S HEAD HAWK MOTHS.

inches across the wings, which are pale brown, varied with darker brown and black; the hind wings are pale pink, crossed by three black bands. The green caterpillar, with white and lilac streaks on the sides, and a black horn on the back, feeds on privet and lilac, and the position which it assumes when at rest suggested that of the mythological Sphinx to the old naturalists, who applied this name to the insect.

The small family of the *Egeriidae*, or Clear-wings, contains a few Moths with transparent wings, the caterpillars of which feed on the stems of trees or plants. In the first genus (*Sphécia*) the body is stout, and not tufted; *S. apiformis*, which may often be found sitting on the trunks of poplars in early summer, looks very much like a large Wasp, being black and yellow, and of about the same size. Another species (*S. bombyciformis*) feeds on osiers.

The species of the other genus (*Trochilium*) are much smaller insects, with long slender bodies, tufted at the extremity. The commonest species, the Currant Clear-wing (*T. tipuliformis*), which measures about three-quarters of an inch across the wings, has transparent wings, with black borders slightly varied with orange, three yellowish rings on the abdomen, and a black tuft at the extremity. It is



CATERPILLAR OF DEATH'S HEAD HAWK MOTH.

common and sometimes injurious in gardens, where its caterpillars live in the shoots of the currant, but the Moth is very liable to be mistaken for some kind of fly.

The family *Zygænide* contains the Green Foresters and the Burnets. The former have thick and obtuse, or slender, antennæ, sometimes slightly pectinated; in the Burnets the antennæ are strongly thickened before the tip. They are all small insects, with rather long fore wings and shorter hind wings, and rather stout bodies: they fly heavily and gregariously in meadows or waste places by day. The Green Foresters (*Ino*) have green fore wings and brown hind wings; the Burnets (*Zygæna*)



DEATH'S HEAD HAWK MOTH.

have steel-blue or greenish fore wings, spotted or streaked with bright red, and the hind wings are of the same colour, which, however, is occasionally liable to be replaced by yellow, as an accidental variation. The yellowish cocoon is often met with attached to the stems of grass, &c. Many of the East



SPHECIA HEXAPODIFORMIS.

Indian species of this family have transparent spots on the fore wings, and some of the South American species are completely transparent. The family *Chalcosiidae* is allied to the last, but the species are larger and adorned with very bright colours. They fly by day, and some species resemble *Papilio* in shape and colour, while others might be mistaken for *Euplexa*. The antennæ, however, are generally simple, and are always unmistakably those of a Moth. These species are East Indian.

The *Lithosiidae*, or Footmen, are a group of Moths with simple antennæ, rather narrow fore wings, and broad hind wings, which are folded beneath when at rest. In the net they usually simulate death. The fore wings are generally grey, with the costa yellow, and the hind wings pale yellowish. The Moths expand about an inch and a quarter, and some species are marked with a few black dots.

The *Arctiidae*, or Tiger Moths, are the most beautiful family of Moths found in Europe. The common Tiger Moth may be taken as typical of the group. It measures from two to three inches across the wings, which are black, with interlacing white markings; the hind wings are red, with large black spots bordered with yellowish. The abdomen is also red, with black markings. The caterpillar is often called "the Woolly Bear," being covered with tufts of long hair, which is black, tipped with white on the back, and reddish-brown on segments 2-4 and on the sides. When disturbed, it rolls itself up into a ball.



ZYGÆNA FILIPENDULE.

COCCON OF
ZYGÆNA
FILIPENDULE.

Most of the other species of this family are similarly coloured, having dark fore wings, with white or yellow markings, and red or yellow hind wings, with round black spots. But some species are less gaudily coloured, and the White and Buff Ermines (*Spilosoma menthastræ* and *tubricipeda*), which are common in gardens, are white or yellowish, with black dots.

Many of the *Lipariidæ* are white Moths, more or less marked with black. The bodies of the females are thick and tufted at the extremity. This tuft is very conspicuous in the Gold-tail and Brown-tail Moths (*Porthesia chrysorrhæa*, and *auriflua*). They are white, with or without a black spot near the anal angle of the fore wings, and measure about an inch and a half in expanse. The eggs are laid in a cluster, and covered by the female with down plucked from the tuft with which she is provided for the purpose. The Moths are common on hedges on summer evenings.

The male of the Vapourer Moth (*Orgyia antiqua*) is about the same size, but has broader and shorter wings. It is orange-brown, with a white spot near the hinder angle of the fore wings, and is a most abundant insect, flying everywhere, about bushes, and even in the streets of London, where there are trees in squares or gardens within any

reasonable distance. The female has rudimentary wings, and looks something like a spider. The Gipsy Moth is a larger insect, very abundant and destructive on the Continent, but rare in Britain. The male, which expands rather more than an inch and a half, has a slender body and broad wings. The female is white, with a thick body and longer wings, and is very much larger than the male. She is generally found resting on hedges or tree trunks in the day-time, while the male flies rapidly by day, like that of *Orgyia antiqua*. In most of the *Lipariidæ* the antennæ are strongly pectinated in the males, and are more simple in the females.

The *Psychidæ* are a family of small Moths, in which the males expand an inch or less, and have uniform blackish or whitish wings, rounded at the extremities. They fly in grassy places by day, and the caterpillars construct movable cases of bits of grass, leaves, &c., not unlike those formed by the larvæ of Caddis Flies. In these they change into pupæ, and the females of some species never leave them, for the females of all the species are apterous, and in some genera the legs and antennæ are undeveloped too.



PSYCHE MŒRELLA.

The *Notodontide* are a family of larger Moths, measuring from half an inch to two inches and a half across the wings, which are rather long, and rounded at the extremity. Many of them are called "Prominents," from a projection on the inner margin of the fore wings. The Moths are generally of dull colours—white or brown, with darker markings, or tawny, with dark lines or white spots on the costa. But the caterpillars are far more interesting from their strange shapes and habits. The first which we shall mention is the Puss Moth, a common insect, of which the caterpillar feeds on poplar and willow.

The Moth measures nearly three inches across the wings, which are white, suffused with greyish, with zigzag blackish transverse lines. The thorax and abdomen are spotted with black. The caterpillar is green, with a large retractile head bordered with red, and a dark mark on the back, varied with greyish-brown or red, and bordered with white. This mark is very broad in the middle (where it is somewhat greenish), and



PUSS CATERPILLAR AND MALE MOTH.

then tapers off towards the tail. The caterpillar has only fourteen legs, the claspers being replaced by two long, slender tubes, from which soft threads can be protruded. This large, green, hump-backed caterpillar, with its forked tail, can hardly be mistaken for any other. There are three species of the same genus found in Britain, which are sometimes called "Kittens" by collectors, but they are much smaller as well as much rarer.

One of the prettiest Moths of this family is *Microdonta bicolora*, which is snow-white, with orange spots on the fore wings, and expands about an inch and a half. It is a great rarity in England.

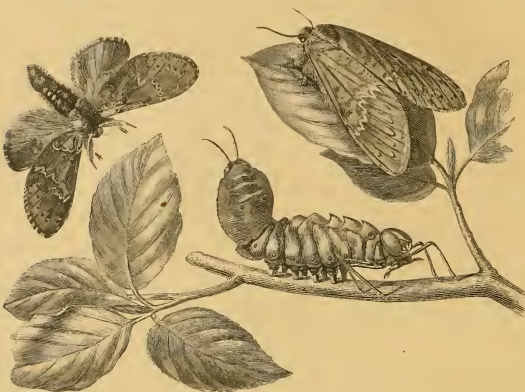
The Lobster Moth (*Stenopus fagi*) is also rather a scarce insect, though much commoner than the last. It is of a brownish-grey, with darker markings, and expands about two inches and a half. The caterpillar is chestnut-brown, with enormously long legs and two projections at the extremity of the body. It feeds on a great variety of trees, and when at rest it stands on its prolegs, and lifts up both extremities of its body, giving it, as may well be supposed from its long front legs, and its two anal appendages, a very odd appearance, which has given the Moth its English name.

The Processionary Moth (*Cnethocampa processionea*) is an obscure, yellowish-grey insect, with darker markings, and expands rather more than an inch. It is only doubtfully British, but is frequently met with on the Continent, where the caterpillars, which are bluish-black on the back and whitish on the sides, feed gregariously on oaks. They form large webs, and go out to feed in regular order, first one, then two, then three, &c. They are covered with fine barbed hairs, and these, as well as the dust in the webs, are so terribly irritating to the skin, that it is scarcely safe to approach the nests; and it is even said that death has sometimes been caused by the swelling and inflammation thus produced.

Another larger species feeds on fir-trees, and is not found so far north as the last (*C. pityocampa*).

The hairs of the caterpillars are just as irritating as those of *C. processionea*, or even more so. These caterpillars march in single file, instead of in an increasing series. The great enemy of both species is a large green Beetle, called *Calosoma sycophanta*.

The only European species of the small family of the *Bombycidae* is the Mulberry Silkworm (*Bombyx mori*). The caterpillar is creamy white and naked, with a hump on the last segment but



LOBSTER CATERPILLAR AND MOTH.

one. Its real food is the white mulberry, but in England it is often fed on lettuce. The Moth measures about two inches, or rather less, across the wings, which are somewhat falcate, and are of a yellowish-white colour, with indistinct dusky transverse lines. The cocoon is yellow or white, according to the breed, and it is from this that the greater part of the silk used in commerce is obtained. The Silkworm was originally a native of China, and Chinese historians attribute the discovery of the use of silk to the Queen of the Emperor Hwáng-tê, who lived about 2640 B.C., and the rearing of Silkworms formed one of the principal duties of the queens and ladies of the court for many centuries afterwards. A great deal of silk is also reared in those parts of India where the climate is sufficiently favourable to the growth of the insect. The Silkworm was first introduced into Europe in the reign of Justinian by some missionaries, who smuggled the eggs to Constantinople concealed in canes. The rearing of Silkworms soon became common, and has ever since formed one of the staple industries of Southern Europe, where the insect has become naturalised in many places. The caterpillar is, however, subject to many diseases, which have greatly diminished the yield of silk of late years. The Moth is not reared in England, except as a curiosity, although it is perfectly able to bear the climate. I am informed that English-grown silk is of very good quality, but that the thread is too short to be of any commercial value. The domesticated Moth is a heavy insect, quite incapable of flight, but if reared in perfect freedom in the open air it recovers the power in a few generations.

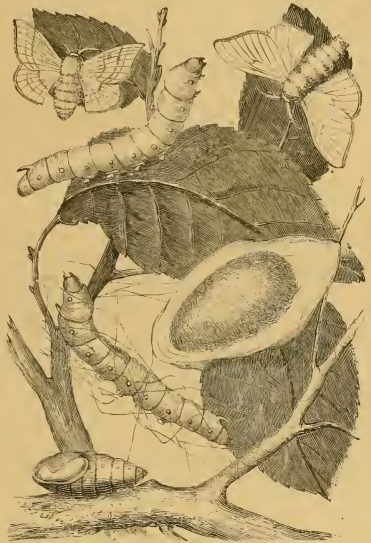
Although *Bombyx mori* is the only Moth reared for its silk in Europe, several other species belonging to other families are used for the same purpose in China, India, and Japan. Most of these belong to the *Saturniidae*, a family which includes many of the largest Moths known, nearly all of which have either a large transparent spot, or a large round eye-spot in the middle of each wing. The antennae are strongly pectinated, especially in the males, and the body is stout, and often very short. The Atlas Moth (*Attacus atlas*) sometimes measures nearly a foot across the expanded wings, which are of a tawny fawn-colour, with a large triangular transparent spot on each. The *Ailanthus* Silkworm (*Attacus cyathia*) belongs to the same genus, but is a much smaller insect, only measuring about five or six inches across the wings. The Moth is of a dull olive-green, with a large transparent bunule, edged below with yellow, on each wing. There is also a broad suffused pink band, edged within

with white and then black, running across all the wings. The caterpillar is yellow, greyish-blue, or green, according to age, and spotted with black. When half-grown it becomes studded with long white tubercles, which secrete a waxy powder. It forms a cocoon resembling brown paper, folded in a leaf of the tree, which is connected with the branch by a silk riband, so that there is no danger of the cocoon falling from the tree when the leaf dies. This insect, which is a native of China, feeds on *Ailanthus glandulosa*, a naturalised tree, is very easily reared, and has been introduced into England, and many parts of the Continent, and has become wild in some places. But as there are great difficulties in successfully winding the silk, speculators have rarely attempted to rear it on a sufficiently large scale to test its actual value as an article of commerce.

A great deal of the silk which is used in Japan is produced by the Oak-feeding Silkworm (*Antheraea yamamai*), which yields a large and beautiful green cocoon of excellent quality. The Moth is a large yellow insect, measuring about seven inches across the wings, which are narrower than in the genus *Attacus*. In the middle of each wing is a round transparent spot. The Japanese Government long reserved the monopoly of this insect to Japan, its exportation being prohibited on pain of death. But notwithstanding this, eggs were smuggled out of the country from time to time, and there is now no restriction on their exportation. Nevertheless, Europe has not yet profited by the introduction of the insect, for although great hopes were based upon it, it is very difficult to rear, and rapidly degenerates in Europe. The cause of its failure has not yet been discovered. Several other closely-allied species are used for the production of silk. Among these is *Antheraea pernyi*, a Silkworm which feeds on the oak in North China; and *Antheraea mylitta*, the Tusseh Silkworm, a common Indian insect, which yields a rather coarse-looking silk, which requires to be carded, for it cannot be wound, but which is so durable that a dress made of it frequently descends from mother to daughter, as it takes more than one lifetime to wear it out.

Several of the Moths of this family have long tails on the hind wings. These are not mere projections, as in many Butterflies, but are more like prolongations of the wings themselves. In the genus *Actias* all the species are tailed, and are of a green or yellow colour, with an eye on each wing. They expand from three to six inches, and most of the species are found in the East Indies, though single species are met with in Spain, Natal, Madagascar, and North America. The genus *Eudemonia* includes a few smaller insects, of a brown or yellow colour, found in Africa and South America; and although they do not measure more than about three inches across the wings, the tails alone are nearly six inches in length in some species.

The only British species belonging to the family *Saturniidae* is the well-known Emperor Moth (*Saturnia carpini*). It measures between two and three inches across the wings, which are grey in the female, whereas the fore wings of the male are reddish-brown, and the hind wings rusty yellow.



CATERPILLAR, COCOON, AND MOTH OF *BOMBYX MORI*.

There is a large black eye in the middle of each wing marked with a white crescent inside, and surrounded with yellow and black rings. The caterpillar is green, with black transverse bands and reddish tubercles, studded with short hair. It feeds on heath, &c., and constructs a hard pear-shaped cocoon. The Emperor Moth is not an uncommon insect, but it is allied to the Great Peacock Moth (*Saturnia pyri*), which measures six inches across the wings, and is the largest Moth found in



CATERPILLAR, CHRYSALIS, AND MOTH OF SATURNIA CYNTHIA.

Europe, but has not been met with farther north than Paris or Vienna. It is a dark-grey Moth with white borders, within which the wings are much darker than elsewhere. The eyes resemble those of *S. carpini*, but are dusted with blue, and the caterpillar is green, with blue warts instead of red ones, and it feeds on different kinds of trees, especially fruit-trees.

The *Lasiocampidae* are large or middle-sized Moths, with stout, hairy bodies, and strong wings, and the caterpillars are clothed with soft hair. The Moths are generally of dull colours—brown, reddish-brown, or yellowish predominating.

The Lappet Moth (*Gastropacha quercifolia*), which is not very common in England, may be known by its reddish-brown dentated wings, marked with zigzag transverse lines. The Oak Eggar (*Lasiocampa quercus*), which is of about the same size, is a much commoner insect, and the hind margins are not dentated. The male is chestnut-brown, and the female ochre-yellow; across the wings runs a broad transverse band of pale yellow, which is much more distinct in the male than in the female, but there is a white spot in both sexes about the middle of the fore wings. The caterpillar is black, with paler hairs, and a white stripe on each side. It feeds on many plants, including oak, and forms an egg-shaped cocoon, whence its name. The male flies very rapidly in the daytime, but may easily be decoyed within reach, if the collector has bred a female from the caterpillar, and carries her alive to a spot frequented by the males. It is not necessary to set her at liberty, or even to keep her in an open box; she will attract the males just as readily if carried in a closed box in the pocket. The Lackey Moth (*Clisiocampa neustria*) is a smaller representative of this family, only expanding about an inch and a half across the wings. The fore wings are either ochre-yellow, with two brown transverse stripes, or brownish-red, with pale yellow ones; the hind wings are paler than the fore wings, and unstriped. The caterpillars are striped with blue, red, and yellow, with a white

line on the back, and they live gregariously on trees under a common web. The Moth is very common in many parts of England, and the female lays her eggs closely glued together in a broad ring round a slender twig.

The *Zeuseride* are rather large Moths, whose caterpillars feed on wood, inside the trunks of trees, often causing considerable damage. The Wood Leopard Moth (*Zeusera asculi*) appears to be commoner round London than elsewhere in England. It is white, with many steel-blue spots on the wings and thorax, and its caterpillar, which is yellow, with a black head, infests apple, ash, and other trees. The Moth measures two inches or more across the wings, and the abdomen is long, and furnished with an ovipositor in the female. The Goat Moth (*Xyleutes cossus*) is a commoner insect. It is shaded with grey and brown, and marked with many irregular black transverse lines. It measures three inches or more across the wings, and is a very heavy-



MOTH AND CATERPILLAR OF SATURNIA PYRI.



LACKEY MOTH AND CATERPILLAR.

looking Moth, with a thick body, which scarcely extends beyond the hind wings. The caterpillar is dirty flesh-colour, with the back brownish-red. It lives in trees, especially poplars and willows, and is not full-grown until it is three years old. Some writers have supposed that this caterpillar was the *Cossus* which was considered a great dainty by the Romans; but it is much more probable that their *Cossus* was the larva of some large wood-feeding Beetle.

The *Hepialide* are a small group with narrow rounded wings, very short antennae, and very long bodies. The largest species is the Ghost Moth (*Hepialus humuli*), which mea-

sures about two inches across the wings. The male is white above and brown beneath, and the female has dull-yellow fore wings, with two oblique red stripes, more or less broken into spots,

and reddish hind wings. The Moth flies in fields, with a peculiar hovering flight, on summer evenings, and its pale yellow caterpillar feeds on the roots of grasses. The other species are much smaller, and are called "Swifts" by collectors. They are brown or yellowish, with white streaks or spots on the fore wings, and their caterpillars feed on the roots of plants. In some species the Moths have the same peculiar hovering flight as in *H. humuli*, but others fly very rapidly near the ground in the evening.



WOOD LEOPARD MOTH.

The great group of Moths known as *Noctue*, or Night Moths *par excellence*, consists of many families, of which we will notice only a few of the most important. Speaking generally, their bodies are rather stout, and extend beyond the hind wings; their antennæ are simple (rarely pectinated), and their hind wings are broader than the fore wings, white, grey, or brown, without markings, or with only a dark spot in the middle, and a dark border, and are folded beneath the hind wings in repose like a fan.

The *Leucanido*, or Wainscots, mostly frequent marshy localities, and measure about an inch and a half across the wings. The fore wings are ochreous or reddish, rarely with transverse lines, but generally with longitudinal white veins and black dashes, and a few scattered black dots. The caterpillars feed either on grasses or in the stems of reeds.

Many of our commonest Moths belong to the *Apanide*. One of these is the Dark Arches (*Xylophasia polygoni*), a brown Moth, measuring nearly two inches across the wings; the abdomen is rather long, and tufted at the extremity. The markings are rather ill-defined, but there is a white line near the border of the fore wings, the lower portion of which forms a W. We find this in many other *Noctue*. The hind wings are paler, and where they join the fore wings are smooth and rather iridescent. This Moth is very common in gardens at dusk, and its caterpillar feeds on the roots of grasses. The Cabbage Moth (*Manestra brassicae*) is an equally common but much more destructive insect. It is smaller and much darker-coloured than the last species, and there is a whitish U-shaped mark on the fore wings. The caterpillar feeds in the heart of the cabbage, and is just as mischievous as those of the common White Butterflies.

The family *Noctuide* includes a great number of dull-coloured Moths, which expand about an inch and a half across the wings. The fore wings are generally brown, with dark spots bordered with paler. The pale submarginal line does not form a W, and the abdomen is not crested, or tufted. The caterpillars feed on low plants, and many of them, mostly belonging to the genus *Agrotis*, feed on the roots of grasses at or below the surface of the ground, and are called by the Americans "Cut-worms." The Moths belonging to the genus *Triphaena* are handsomer and more conspicuous than the other species of this family, as the hind wings are yellow, with a black band, varying in width according to the species, before the hind margin. They are called "Yellow Underwings."



CLIFFDEN NONPAREIL.

The *Orthoside*, or Chestnuts, include a number of smaller species, expanding about an inch and a

quarter. Most of these have grey, reddish, or yellowish fore wings, and whitish hind wings, and the abdomen is rather short. They may be met with in spring and autumn, and frequent the flowers of the willow and the ivy. One of the largest species is the Satellite (*Scopelosoma satellitia*), which sometimes expands nearly two inches. The fore wings are reddish, and there is a white or orange spot in the middle, between two small dots. The hind wings are reddish-white. The caterpillar is blackish, with white lines on the back, and white spots on the sides. It feeds on a variety of trees, but will also devour any other caterpillars in whose company it may find itself.

The *Hadenide* are a group of Moths much resembling the *Apamide*, and generally with the pale subterminal line forming a very distinct W. But the beautiful Angleshades Moth (*Phlogophora meticalosa*) is an exception. The triangular and slightly dentated fore wings are olive-brown, or ochreous, varied with rosy, and the outer pale line is indistinct; the hind wings are yellowish-white.

The *Xylinide* are a small family, including, among other genera, the genus *Cuenellia*. The Moths belonging to it are called "Sharks" by collectors, and their fore wings and abdomen are long and pointed. The former are generally ochreous or greyish, with hardly any markings, the costa and hind margin alone being bordered with a darker colour. In some Continental species, however, the fore wings are beautifully marked or streaked with silver, and sometimes with green. These Moths expand about one inch and a half.

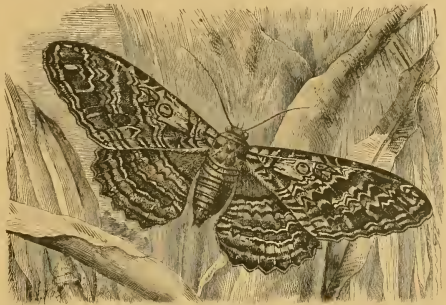
The *Heliothide* are day-flying insects, and one of the commonest species is the Beautiful Yellow Underwing (*Anarta myrtilli*), which is found on heaths. The fore wings, which expand about an inch, are red, with white lines, and the hind wings are orange, bordered with black. Two other species are found in Scotland; but many others are found in Lapland, and other countries in the north of Europe and America. Of these, some have yellow, and others white hind wings.

Several of the *Pluside* are also day-flying Moths. The well-known Gamma Moth, or Silver Y (*Plusia gamma*), is one of these. The fore wings are violet-grey, with a silvery Y-shaped mark in the middle. The hind wings are of a paler grey, without markings. Other species of *Plusia* fly in the evening, among which is the Burnished Brass Moth (*P. chrysis*), the fore wings of which are pale brown, but almost covered by a large irregular brassy-green patch. Most of the other species of the genus are either marked or spotted with silvery, golden, or brassy in a similar manner.

The *Amphippriide* are a small family with rather short and broad wings; and as the British representative of it, we have chosen a larger Moth than any *Noctue* yet noticed

—*Mormo maura*—a dark grey insect, with blackish bands, measuring about two inches and a half across the wings. It is very common in gardens on summer evenings, and often flies into houses. Its flight is rather heavy, and it is called "The Old Lady" by collectors.

The *Catocalide*, so called from two Greek words, meaning "beautiful beneath," are the largest and handsomest *Noctue* found in Europe. The fore wings are grey, varied with lighter and darker zigzag lines and blotches, assimilating them to the appearance of the lichen-covered trunks of trees, on which they prefer to rest. But the hind wings are black, with a pale blue band across, in the rare Clifden Nonpareil (*Catocala fraxini*), while the other species have red hind wings, with black borders, and a black band across the middle. They are all large insects, measuring from two and a half to



GREAT OWL MOTH OF BRAZIL.

four inches across the wings. Many of the European species have yellow hind wings (and these are generally smaller than the red species), and in North America, where there is a much greater variety of *Cotocala* than in Europe, many species have black hind wings, with a narrow white border. The caterpillars have the first pair of prolegs imperfectly developed, and arch their backs a little in walking. They are sometimes called "Half-Loopers."

The *Ophideridae* are a family of tropical Moths, generally measuring about three inches across the wings, which are long, rather narrow, and a little pointed. The hind wings are yellow, partly bordered with black, and with a thick curved black mark in the middle. The palpi are long, and curved upwards, and the proboscis is short, and very strong. These Moths are very destructive to oranges in Australia; but it has not yet been ascertained with certainty whether they perforate

the rind themselves with their strong proboscis, or whether they avail themselves of any injury which the fruit may have previously received, in order to suck out the contents.

The largest *Noctua*, and one of the largest Moths known, is the Great Owl Moth of Brazil (*Thysania agrippina*), which belongs to the family of the *Erebidae*. It measures nearly a

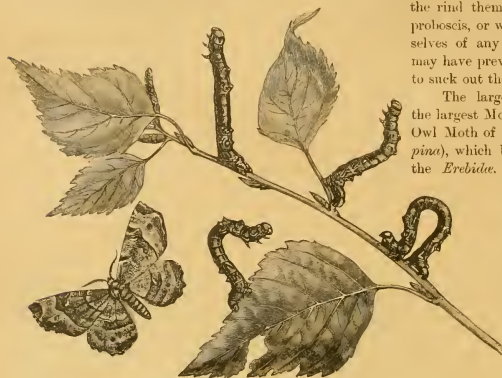
foot across the wings, which are pale grey, with darker markings, and the hind margins are scalloped. But the wings are not remarkable for their breadth, so that the Atlas Moths are larger insects on the whole.

The small family of the *Deltoidae*, which is sometimes placed

with the *Noctuae* and sometimes with the *Pyrules*, may be illustrated by the "Snout" (*Hyppena proboscidalis*), a brown Moth, with rather slender body, and very long palpi, resembling a beak. It measures about an inch and a half across the fore wings, which are broad and triangular, and is a very common insect among nettles.

The *Geometrae* (or Land Measurers) are an extensive group of Moths known as "Loopers" in England, on account of the peculiar structure of the larvæ, which have only ten legs, the two first pairs of prolegs being absent. When they wish to walk, they fix themselves firmly by their last pair of prolegs (the only pair which they possess) and their claspers, and stretch out their bodies to their greatest length; then, fixing themselves by the six true legs, they loosen their hold with the four hinder ones, which they draw closely up to their front legs, thus arching their body into a loop; they then fix themselves again by their hind legs, stretch out the front of their bodies, and proceed as before. This peculiar mode of walking is very rapid; and their mode of rest is not less singular, for they fix themselves by their four hind legs, and stretch their bodies stiffly out, sometimes remaining motionless for hours. In this position they present a remarkable resemblance to a dead twig, and thus often elude the observation of birds and other enemies. The Moths are generally broad-winged insects, with slender bodies. They fly at dusk, but may often be disturbed in the daytime by beating hedges. The wings are rarely dentated or angulated, and are often brightly coloured, the pattern of the fore wings being generally continued on the hind wings.

The family *Urapterygidae* contains only one British species, the Swallow-tail Moth (*Urapteryx sambucaria*), which measures about two inches across the wings; the hind wings are angulated outwards into



ENOMOS ILLUSTRARIA AND CATERPILLARS.

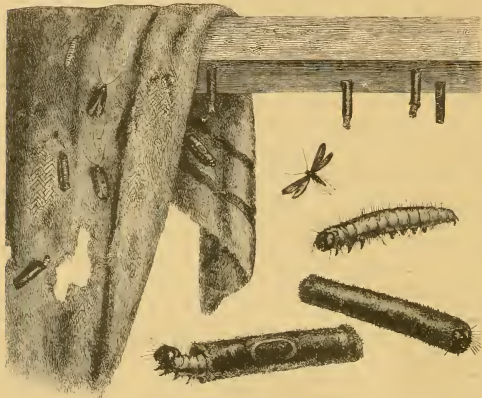
a short tail. It is of a very pale yellow, with two olive-brown lines on the fore wings, and one on the hind wings, and two small brown dots at the root of the tail. The family *Ennomidae* includes smaller insects, mostly of a yellow colour. Among these is the well-known "Brimstone Moth" (*Ituna crataegata*), so common in hedges. It measures about an inch and a half across the wings, which are sulphur yellow, with rust-coloured spots on the costa. The genus *Ennomos* includes insects of a paler yellow, marked with transverse lines. Their bodies are rather thick, the thorax is covered with a close fur above, and the hind margins of the wings are irregularly dentated. The family *Amphidasidae* includes dull coloured Moths with stout bodies. They appear in spring, and one of the commonest is the Pepper and Salt Moth (*Amphidasis betularia*), which is white, speckled with black, and with more or less distinct black costal spots and transverse lines. Some of the allied species have apterous females. The family *Geometridae* includes a number of broad-winged green species, with whitish transverse lines. Their bodies are rather slender, and the wings, which expand from one to over two inches according to the species, are seldom angulated. These Moths are usually called "Emeralds," on account of their colour. The *Acidulidae*, or "Waves," comprise a large number of small species, generally of white, ochreous, brownish, or reddish colour, with dusky, or occasionally reddish lines. The Heath Moths, or *Fidonidae*, fly by day, and several species, tessellated with cream-colour and black, are very common. The *Euschemidae* are an East Indian group of large Moths, which have only lately been referred to the *Geometra*, on account of the discovery of their transformations. The Soldier Moth (*Euschemu militaris*) is the commonest. It expands about three inches, and the wings are bright yellow, with bluish-black lines and spots, and the fore wings have a broad bluish-black border, spotted with white. The Magpie Moth (*Abraxas grossulariata*) belongs to the family *Zereneidae*. It is common in every garden, and varies very much, but is generally white, spotted with orange and black at the base of the fore wings, and with an orange stripe across the middle, bordered with black spots on each side. The hind margins of all the wings are spotted with black, and there are several other black spots. The body is yellow, spotted with black. The Moth expands rather more than an inch and a half, and the caterpillar feeds on gooseberry and currant bushes. Several brownish or yellowish Moths, with darker transverse lines, belonging to the families *Hypernidae* and *Larentidae*, are found only in winter. It is remarkable that most of these have apterous females, as is likewise the case with some of the *Amphidasidae*, which appear in very early spring. The large family *Larentidae* includes a great number of other Moths with brown and white wings, arranged in festooned patterns, which has led to their being called "Carpets." Some of these are white, with black lines; and in the genus *Lobophora*, there is so large an additional lobe to the hind wing as to give them the appearance of having six wings, whence they are called "Seraphims" by collectors. These Moths seldom measure more than an inch and a half across the wings, but the great genus *Eupithecia* includes a number of smaller species (called "Pugs"), seldom expanding an inch across the wings, which are generally brown, with darker transverse markings, though a few are varied with white or green. Their small size, and the indistinct character of the markings, render most of the species difficult to distinguish from each other. The *Erastinidae* are a South American family of Moths, ornamented with bright colours, such as red, black, and white. The fore wings are triangular, and the hind wings are produced and often tailed. These insects look very unlike Moths, and, but for the filiform antennae, might readily be mistaken for *Erginidae*.

The *Pyrales* are a group of small Moths, with rather long wings, and long and slender bodies. The Meal Moth (*Pyralis farinalis*), belonging to the family *Pyralidae*, is one of the commonest. It measures about an inch across the fore wings, which are dark chocolate brown at the base and tip, and dull yellow in the middle, the colours being separated by white lines; and the hind wings are bluish-grey, with white lines. The caterpillar feeds on flour, as well as on straw, &c., and is sometimes found in meal-tubs. The most beautiful species of this group belong to the *Ennychidae*. The species of *Pyrausta* are common in waste places in many parts of the country, flying by day. They are small Moths, not exceeding three-quarters of an inch in expanse, and the fore wings are red, with golden yellow lines or spots. The *Hydrocampidae* are small white Moths, about an inch in expanse, found in marshy places or ponds; the caterpillars feed on water-plants. They are white, with black, and occasionally yellowish, lines or markings, and are known as "China Marbles." The *Botyde* are often called "Pearls," on account of the slightly shining appearance of some of the species. Two of

these (*Botys verticalis* and *urticalis*) are common among nettles, on which the caterpillars feed. They expand about an inch and a half. The former is pale, shining, yellowish-white, with grey markings, and the latter is white, with a row of connected dark spots on the borders, and a row of more separated spots within. The base of the fore wings is yellow, and beyond it are several large dark spots.

The *Crambi* may be known by their very narrow fore wings, and very broad hind wings, which are folded round the body when at rest. The two principal families are *Phycide* and *Crambide*. The former are small and frequently dull-coloured Moths, many of which live on dried fruits in the caterpillar state, and are consequently common in warehouses. A few years ago an enormous white web, many feet in length and breadth, formed by the caterpillars of *Ephestia elutella*, was found on the wall of a chicory warehouse at York. The *Crambide*, or Grass Moths, generally have brown or straw-coloured fore wings, intersected by a white or silvery longitudinal streak; the hind wings are brown, and the palpi project in front of the head, forming a kind of beak. They are easily disturbed when we walk through long grass, but they soon settle again, when the long cylindrical form which they assume when at rest makes them difficult to find. The small family of the *Galleride* are remarkable for their caterpillars feeding on wax in bee-hives, where they sometimes cause great mischief.

The *Tortricide*, or Bell Moths, may be known by their broad truncated fore wings, which meet



CLOTHES' MOTH.

together over the back, and give the insect somewhat of the shape of a bell when at rest. The caterpillars generally live in rolled-up leaves, but some feed on fruit, roots, &c.; a few form galls. The maggots which infest our apples and plums are the caterpillars of species of the genus *Carposcopa*. There is a Mexican species (*C. saltitans*), the caterpillar of which lives in the seeds of a Euphorbiaceous plant, and possesses the faculty of leaping, carrying its house with it. There are about three hundred specimens of *Tortricide* found in Britain; one of the commonest is the Green Oak Moth (*Tortrix viridana*).

It measures nearly an inch across the fore wings, which are green, whereas the hind wings are brown, and it may often be dislodged in a perfect shower, if an oak tree be shaken.

The *Tineæ* are a very numerous family of small Moths, to which belong nearly one-third of the Lepidoptera of Britain. Their bodies are slender, and their wings are long and narrow, with very long fringes. There is a great diversity of form, markings, and habits among them. The *Tineide*, or Clothes' Moths proper, generally feed on dried animal substances, such as cloth, hair, or feathers, though some species feed on corn, &c. They often feed both on and in their food, those that attack clothes forming a tube of the substance on which they feed, in which they live, and which they enlarge when necessary. The *Adelide*, or Long Horns, are green, sometimes streaked or spotted with yellow. They may be known by their very long antennae, which are about three times as long as the expanse of their wings. The genus *Depressaria*, belonging to the great family *Gelechiide*, contains dull-coloured Moths, with rather broad and flattened bodies. They are rather large for *Tineæ*,

many species measuring nearly an inch across the wings. Many of the larvae of the *Coleophoridae* form cases on various plants, like the *Psychidae*; those of the *Elachistidae* live in the stems of grasses. Those of many groups of *Tineae* live in blotches or galleries made in the interior of the leaves of different plants. Among these are the *Nepticulidae*, to which family belongs the smallest Moth known (*Nepticula microthelella*), which measures only about the eighth of an inch across the wings, which are purplish-brown, with a whitish mark beyond the middle. The caterpillar feeds in the leaves of the nut, &c., and twenty or thirty mines may often be seen in a single leaf, according to Mr. Stainton. The perfect insect has never, so far as I know, been observed at large, on account of its very small size. All the specimens in collections are bred.



ALUCITA HEXADACTYLA.
(Natural Size and Magnified.)



PTEROPHORUS PENTADACTYLUS.
(Natural Size and Magnified.)



The Plume Moths (*Pterophoridae*) may be known from all other Moths by the fore wings being cleft into two distinct feathers, and the hind wings into three. Most of the species are brown or grey, but the commonest, the White Plume Moth, found in gardens, is nearly pure white. It expands rather more than an inch across the wings, and is a very delicately-formed insect, with long slender legs. The only British representative of the family, *Alucitidae* (*Alucita hexadactyla*, the Twenty-plume Moth), is a small brownish insect measuring three-quarters of an inch across the wings, each of which is split into six separate feathers. It is common in gardens, &c., and the caterpillar feeds on the buds of the honeysuckle.

FOSSIL BUTTERFLIES AND MOTHS.

On account of their fragile nature, very few Lepidoptera have been found in a fossil state. Some entomologists are said to have described fragments of fossil leaves as the remains of Butterflies, and there is much difference of opinion about other supposed Lepidopterous remains, which are undoubtedly those of insects, some authors maintaining that they are Lepidoptera, while others refer them to the orders Neuroptera or Homoptera. Consequently, as regards remains admitted by all to be those of Lepidoptera, it is not surprising that different entomologists refer them to different genera, and even families. The oldest reputed Lepidopterous fossil is Mr. Butler's *Paleontina oolitica*, but the position of this fossil has been questioned by some authors, though many consider it as Lepidopterous. Mr. Scudder, who has paid special attention to fossil insects, admits only ten species of fossil Butterflies (all of the Tertiary period), one American, and the rest European, which he refers to the families *Nymphalidae* (*Satyrinae* and *Nymphedinae*), *Papilionidae* (*Pierinae* and *Papilioninae*), and *Hesperiidae*. Most of these have been obtained from Aix, in Provence, but one or two have been found in Croatia and in Western Germany. Scudder regards the nine European species as exhibiting decided Indo-Malayan and Tropical American affinities, one only being related to African, and one to existing South European forms. Concerning fossil Moths still less has been published; nevertheless, several species have been recorded, belonging to nearly all the leading groups. The oldest of these (*Sphinx suelleni*) is from the Solenhofen Slate, as is also the doubtful Butterfly (*Paleontina oolitica*) to which we have already alluded.

W. F. KIRBY.

CHAPTER XII

DIPTERA—APHANIPTERA.

DIPTERA—Characters—The Proboscis—Structure—Metamorphosis—Internal Anatomy—Habits—Parasitism—Distribution—Classification—**TRIBE NEMOCERA**—THE **CULICIDÆ**, OR **GNATS**—Metamorphosis—Habits—Blood-thirstiness—The Mosquito—Other Gnats—THE **CHIRONOMIDÆ**—THE **TYPULIDÆ**—THE **CRANE FLIES**, or **Daddy Long-legs**—The Giant Crane Fly—The Genus *Ctenophora*—Midges—Other Genera—THE **MYCETOPHILIDÆ**—Fungus Midges—The Army Worm—THE **CECIDOMYIDÆ**, or **Gall Midges**—The Hessian Fly—Its Destructiveness—The Wheat Gail—Another Pest—The Galls—Dr. N. Wagner's Observations on the Genus *Miasor*—THE **PSYCHODIDÆ**—THE **LIBIONIDÆ**—"Garden Flies"—"Sand Flies"—The *Columbatch Fly*—**TRIBE NOTACANTHA**—THE **STRATIOMYIDÆ**—**TRIBE TANYSTOMA**—THE **TABANIDÆ**, or **Breeze Flies**, or **Gad Flies**—Habits—The Ox Breeze Fly—The Golden-eyed Breeze Fly—The CLEGG—A "Blood-drinker"—THE **ASILIDÆ**—THE **THEREVIDÆ**—THE **EMPIDÆ**—THE **ACRO CERIDÆ**—THE **BOMBILIDÆ**—THE **LEPTIDÆ**—THE **DOLICHOPODIDÆ**—THE **PLATYPEZIDÆ**—THE **SCENOPINIDÆ**—**TRIBE ATHERICERA**—THE **SYRPHIDÆ**—Parasitism—The *Volucella*—The Genus *Eristalis*—THE **MUSCIDÆ**—Characters—The *Tachinaria*—The *Muscaria*—The Common House Fly—The Bluebottle—The Flesh Fly—The Greenbottle Flies—The Tsetse Fly—The *Acalyptera*—Various Genera—The *Phorides*—The *Œstrides*—The *Œstrus bovis*—The *Cephalomyia*—*Gastus*—**TRIBE PUPIPARA**—THE **HIPPOBOSCIDÆ**—THE **NYCTERIBIDÆ**—THE **BRULIDÆ**—**APHANIPTERA, THE FLEAS**—Characters—Classification—Transformations—Habits—Various Species—Their Muscular Energy—Trained Fleas—The Jigger—Its Pernicious Parasitism.

THE Diptera agree with the Lepidoptera in having a suctorial mouth and a perfect metamorphosis, but differ from them in so many particulars that there is no difficulty in distinguishing them—in fact, the order is one of the best characterised in the whole class of insects. They may be



DIPTEROUS INSECTS—*VOLUCELLA PELLUCENS* AND
CERIA CONOPSOIDEA.

defined as insects with a perfect metamorphosis and a sucking mouth; with the prothorax ring-shaped and all the segments of the thorax united into a mass; with only two wings, which are membranous, naked, or more or less hairy, attached to the mesothorax, while the hind wings are represented by a pair of small knobbed organs called halteres. These characters of the wings will serve to distinguish the Diptera at once from the Hymenoptera, with some of which certain species of flies might be confounded at the first glance.

The mouth, although a sucking organ in the strictest sense of the term, differs completely

from that of the Lepidoptera in the nature of the modifications by which its parts are adapted to their peculiar functions, and especially in the fact that, whereas the actual proboscis of the Lepidoptera is formed by a single pair of the fundamental organs of the mouth, that of the Diptera may include and bring into action the whole of those parts. The visible proboscis itself is composed of the lower lip (*labium*), which may be either horny or fleshy in its texture, and is often capable of bending a little way from its base, and of being retracted within a cavity of the under surface of the head. It varies greatly in length, being sometimes quite short and easily concealed, sometimes very long, even much longer than the whole body. The tip is sometimes more or less pointed, sometimes blunt, and then often terminated by a pair of fleshy lips forming a sort of cleft disc, in the middle of which the aperture of the mouth is situated. This structure may be well seen in the common House Fly, or the Meat Fly. But whatever may be its external peculiarities, the proboscis consists of the *labium* produced into a more or less tubular form, and cleft more or less widely along the upper or front surface. This cleft is closed by the *labrum* or upper lip, which is elongated so as to reach towards the tip of the proboscis, and, although considerably narrower than the *labium*, is also curved into the form of a half tube with its concavity turned towards that of the *labium*.



HEAD OF FEMALE
GNÂT.

a, antennæ; *l*, *labrum*; *e*, *epipharynx*; *m*, *mandibles*; *m'*, *maxillæ*; *p*, *palpus*.

Within the tube of the proboscis we find several bristles, often flattened and of a lancet shape, the office of which is to penetrate the tissues of plants and animals, and set free the juices upon which

these insects feed, which are then easily sucked up through the proboscis. These bristles, or lancets, which are the elongated representatives of the organs of the mouth, are somewhat variable in number. When they are most numerous there are five of them, namely, two pairs, representing the mandibles and maxillæ, and an unpaired superior bristle, which is attached to the base of the labrum, or close to it above the pharynx, and is therefore called the *epipharynx*. The number is reduced by the suppression of some of the bristles—usually to three, one pair and a single superior one—and it is then a question whether the upper unpaired bristle is still to be regarded as the *epipharynx*, or whether the latter is suppressed and the third bristle composed of the two representing the mandibles united into a single organ. The latter view is the one now generally adopted. The number of bristles may vary even in the two sexes of the same species, as is the case in the common Gnat, of which the female alone possesses the full complement. The labium itself has no palpi, but the bristles representing the maxillæ have these appendages, which are frequently of considerable length and composed of several joints. The palpi project from near the base of the proboscis, from which, indeed, they actually spring in many instances (as, for example, in the common House Fly). This is due to the fact that in these insects the part of the maxillæ bearing the palpi is amalgamated with the base of the labium into a single mass.

The head in the Diptera is very freely attached to the front of the thorax by a short and usually slender neck, an arrangement which renders it very movable, it is generally of a rounded form, but not unfrequently flat or even concave behind. The compound eyes are well developed, except in a few forms, in which they are rudimentary or altogether wanting. They are usually large, often covering nearly the whole upper surface of the head, and leaving only a small triangular space on the top for the three ocelli, which are generally present, and another small space in front for the attachment of the antennæ. The eyes are generally larger in the males than in the females, and often meet in the middle line, whilst in the females they are separated by a narrow band.

The antennæ, which are generally inserted upon the face between the eyes, vary considerably in size, form, and structure, but we can distinguish two principal types of these organs. In the one (see figure of head of female Gnat on p. 70), the antennæ are more or less elongated and composed of a considerable number of joints, when they are either thread-like or beaded, and often, especially in the males, hairy or feathered throughout; in the other, they consist apparently only of three joints, of which the last is usually a good deal longer than the others, and not unfrequently shows signs of its being really composed of several joints in the shape of notches or transverse lines. These antennæ sometimes project in front of the head, and sometimes hang down close in front of the face. The third joint is very commonly furnished with a long bristle, which may be jointed, and thus indicates that it is a continuation of the ordinary jointed antennæ. This bristle, which is often hairy or feathered, may spring either from the extremity or from the back of the third joint (see Vol. V., p. 284, Fig. 5, E).

As in the Lepidoptera, the three segments of the thorax are soldered together to form a single mass. The mesothorax, as bearing the wings, is most largely developed; the prothorax is generally reduced to a very small ring; and the metathorax is usually confined to the hinder surface of the thorax. The hinder part of the mesothorax is cut off by an impressed line, and forms a distinct scutellum. The wings, of which, as already stated, only the first pair are developed as organs of flight, although sometimes dark-coloured or spotted, are generally transparent, and either composed of naked membrane or more or less clothed with hairs. The veins for the most part run, branching more or less, through the length of the wing, but in many species there are cross-veins which enclose complete cells, like those of the Hymenoptera, although we never find, as in the latter, a stigma with a regular system of cells in its vicinity. Close to the base of the inner margin of the wing, in a great number of Diptera, we find the margin of the membrane cut into one or two small lobes by notches of variable depth. The outer one, which is clearly a portion of the wing, has been called the *alula*; the inner one, which is attached to the thorax, is the *scale* (*squamula*), and, when most developed, forms a sort of roof-like covering for the *halteres*, or appendages of the metathorax. The latter, the nature of which has been the subject of considerable discussion, are now generally regarded as representing the hind wings. They are small organs resembling the clapper of a bell, composed of a thin stalk bearing a knob at its

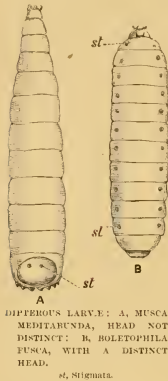
extremity. These organs are in a constant state of vibration, but what their special function in the economy of the insect may be is unknown.

The three pairs of legs, which are articulated to the lower part of the thorax, exhibit a considerable variety of development, being sometimes of moderate length and stout or even thickened, sometimes excessively long and slender, and exhibiting every intermediate form. They are, however, always articulated to the thorax by a conical coxa, have a ring-shaped trochanter, and five-jointed tarsi, of which the first joint is generally much longer than any of the rest: the last joint has at its extremity a pair of claws, and either two or three membranous appendages (*pulvilli*).

The abdomen, which may be attached to the thorax either by its whole base or by a slender stalk, consists of from five to eight segments, but generally shows no external peculiarities, except the appendages to the generative organs which frequently project from its apex, and are sometimes very complicated in the males.

Throughout the order the larvæ are footless grubs, generally with a soft body, but sometimes leathery, or even nearly horny. Many of them possess a distinctly marked head, which may bear ocelli, but in the majority the head does not differ from the other neighbouring segments, within which it can be retracted. The mouth is frequently provided with a pair of horny hooks, by means of which the larvæ cling to the objects from which they obtain their nourishment. This consists in all cases of fluid materials derived from animal and vegetable substances. The larvæ frequently live in the substance upon which they are feeding; others reside in the water, and many are parasitic.

When the larva is full grown the change to the pupa state takes place in two different ways. In some the larva skin is cast, and the pupa makes its appearance in a form more or less resembling that of the *Lepidoptera*, that is to say, the wings, limbs, antennæ, and other parts of the body are shown, only enclosed within a membrane; while in others the larva skin is retained and becomes hardened, so as to form a case within which the insect changes into a pupa. The escape of the perfect insect in these latter cases is usually effected by the separation of one end of the case, like a sort of cap, the agency by which the rupture is effected being, in many cases if not in all, a peculiar bladder-like inflation of the forehead



DIPTEROUS LARVÆ: A, *MUSCA* MEDITARUNDA, HEAD NOT DISTINCT; B, *BOLETOPHILA* FUSCA, WITH A DISTINCT HEAD.

st, Stigmata.

which is afterwards effaced. Many of the free pupæ are provided with sharp hooked processes upon the head and thorax, which are of service to them in making their way out of their places of shelter when about to give birth to the perfect insect; those of the species living in water are active, and swim vigorously by the action of the abdomen.

The respiration of the larvæ is effected by stigmata, but there is considerable difference in the arrangements of these organs. Many larvæ, including the great majority of those provided with a distinct head, have the stigmata, or breathing pores, placed along the sides of the body, two on each segment, as in the majority of the insects which have already been described; but in a still greater number, including all those commonly called headless larvæ, or in common parlance, *maggots*, the stigmata are indeed often indicated on the sides of the segments, but these are not perforated, and the only efficient respiratory openings are a pair of stigmata situated at the hinder end of the body, usually upon a flattened surface which terminates it posteriorly. Some head-bearing larvæ, however, which live in water, such as that of the common Gnat, have their sole efficient respiratory aperture situated at the hinder end of the body, where it forms a longish tube, the extremity of which can be brought to the surface of the water for the admission of air to the tracheæ, and a somewhat similar provision is met with in some headless larvæ.

In a good many species of the order the larvæ are hatched within the body of the mother, and in one whole group, which is distinguished by other peculiarities, they are not only hatched but



COMMON HOUSE FLY EMERGING FROM THE PUPA.



DIPTEROUS FLIES.

A, *Tipula hortulana*; B, *Ctenophora pectinicornis*; C, *Stratiomys chamaeleon*; D, *Takenus bovinus*; E, *Asilus germanicus*; F, *Volucella pellucens*; G, *Syrphus pyrastris*; H, *Chrysops caecutiens*; I, *Eristalis tenax*; K, *Tachina grossa*.

retained and nourished in the egg-passages until they are ready to pass into the pupa state, and are born in this condition.

As regards the internal structure of the Diptera, it may be mentioned that, like the Lepidoptera, they possess a sucking stomach which originates from one side of the œsophagus; that they have four, or sometimes five, Malpighian vessels, which not unfrequently unite to form one or two ducts by which their secretion is discharged into the intestine; that the two main trachean stems exhibit bladder-like dilatations, which are often of considerable size in the base of the abdomen; and that the central nervous chain varies greatly in structure in accordance with the general form of the body, the elongated species having three distinct thoracic and five or six abdominal ganglia, while in some stout-bodied flies the whole of the ganglia seem to be united into a single mass.

The Diptera are for the most part active day-flying insects, like the Hymenoptera, which some of them closely resemble in appearance and in haunting flowers, upon the sweet juices of which they feed. There is a further resemblance between the Diptera and the Hymenoptera in the prevalence of the habit of parasitism in certain groups of both; and in both orders we find species whose larvæ reside and feed in the interior of excrescences produced upon plants by the irritation of their presence. In the Hymenoptera, however, we have no examples of the bloodthirsty propensities which characterise so many Diptera. Apart from these and some other forms which are either annoying to ourselves or injurious to our property, the Diptera must be regarded as acting a beneficent part in the economy of nature. Thus, so far as we are concerned, the parasitic and some predaceous species act as a check upon the multiplication of many other insects which are enemies to the gardener and agriculturist: while a great number of others seem to have a special mission to clear away all sorts of decomposing animal and vegetable matters which, if left, would seriously contaminate the air.

From the imperfect knowledge that we possess of the exotic species of this order, it is not an easy matter to arrive at any trustworthy estimate of the total number of species included in it. Dr. Schiner, of Vienna, estimates the known European species at about 9,000, and these he regards as not more than a twentieth part of the whole. Allowing for probable exaggeration in the estimate of European forms, this would give 150,000 or 160,000 as the total Dipterous population of the globe.

As regards their geographical distribution, the Diptera show a remarkable uniformity, the principal families being generally represented in most regions, and many genera, and even species, having an exceedingly wide distribution. The largest and finest species in this, as in other orders, are generally inhabitants of warm climates. In their geological history, the Diptera agree generally with the Hymenoptera. No Palæozoic Diptera have been recorded. Among the Secondary rocks the Rhætics are the earliest in which remains of Diptera are supposed to occur, and these are regarded as very doubtful. The Lias of Schambelen in Switzerland, which has yielded Professor Heer such an important assemblage of insects of various orders, contains no Diptera, and it is not until near the close of the Mesozoic period that undoubted remains of Diptera were preserved in the lithographic slates of Solenhofen and in the Purbecks of Dorsetshire and of Wiltshire and Buckinghamshire. These represent several still existing families. A few fragments of wings occur in the Wealden; but in all Tertiary deposits Diptera occur in constantly increasing number and variety, but all referable to families and usually to genera still living on the earth.

The Fleas (*Aphaniptera*) have of late years commonly been regarded as aberrant members of the order Diptera, but for various reasons we have preferred here to revert to the old view, never entirely abandoned by naturalists, that these insects form a distinct order. The remainder, characterised in general as above described, may be divided into two groups, in accordance with a very important difference in their mode of reproduction. In the first and most typical group, the females produce their young either in the egg state or as young larvæ; in the second, the hatched young are retained within the oviduct until they are full grown, and only extruded when they are just about to pass into the pupa stage. These latter, to which the name of *PTUPARA* has been given, differ from the rest of the order in several points of structure; thus, the head is either very closely applied to the front of the thorax, or actually immersed in a cavity formed in that part for its reception, the antennæ are excessively short, and usually immersed in cavities of the front of the head, and the maxillæ form a sort of sheath for the labrum, the actual piercing organ consisting only of these three bristles. The remainder, which exhibit, with

many minor modifications, the normal structure of the order, may then constitute a great group under the name of *DIPTERA GENUINA*, which is already sufficiently characterised.

The classification of the *Diptera* is a matter of some difficulty, and several different systems have been proposed. Until of late years, however, the order was usually divided into two main sections, the *Nemocera* and the *Brachycera*, or long and short-horned types; but other arrangements have been proposed, generally founded, more or less, upon the character of the metamorphosis, the most complete of which is that invented by MM. Brauer and Schiner, which rests almost wholly upon the study of the preparatory states of the insects. This classification, however, we shall not adopt here, partly because the groups thus formed cannot always readily be characterised by peculiarities of the perfect insects, and partly because it is quite uncertain how far minor peculiarities of the larvæ and pupæ are to be regarded as of importance in classification. The arrangement of the families here followed is very nearly that adopted by Dr. Gerstæcker in the "*Handbuch der Zoologie*," but we have introduced some higher divisions, which are the same as those proposed many years ago by Latreille and adopted by Professor Westwood in his admirable "*Introduction to the Modern Classification of Insects*." The characters distinguishing the *Pupipara*, the lowest of our divisions or tribes, from the rest of the *Diptera*, have already been indicated, and we have therefore now only to consider the "*Diptera genuina*." These may form four tribes.

1. *NEMOCERA*, having the antennæ usually composed of from ten to seventeen joints, but sometimes of only six, thread-like or beaded, and the palpi of four or five joints, the cross-veins in the wings usually few or altogether wanting, and the halteres uncovered. The larva is furnished with a more or less distinct head, and gives origin to a free pupa.

2. *NOTACANTHA*, having the antennæ composed of not more than twelve joints, which, when most numerous, are sometimes nearly equal, forming a thread-like antenna, as in the preceding division, but more commonly constitute apparently a three-jointed organ, of which the third joint is ringed; the palpi of not more than three joints; the veins of the wings usually forked and with cross-veins, and the halteres uncovered. The larva has a more or less distinct head, and the pupa is enclosed in the dried larva skin, from which it escapes, when mature, through a slit in the back.

3. *TANYSTOMA*, in which the antennæ consist apparently of three joints, but often with indications of articulations in the third joint, and with a terminal bristle; the palpi of not more than two joints; and the mouth usually more perfect than in the preceding group. The larvæ have a more or less distinct head, and produce free pupæ.

4. *ATHERICERA*, having the antennæ composed of three joints, of which the third shows no indication of rings, but is furnished with a bristle which is often more or less jointed; the proboscis kneed, usually retracted and concealed when not in use; the palpi of a single joint, and the mouth with only two or three bristles. The larvæ have no distinct head, and the pupa is enclosed within the dried larva-skin, which contracts into an oval form.

5. *PUPIPARA*, already characterised (p. 73).

TRIBE I.—*NEMOCERA*.

As already described, the *Nemocera* have thread-like or beaded antennæ, and these organs are usually of considerable length, and composed of somewhat numerous joints. In many cases, especially in the males, they are fringed or surrounded with long hairs, which give them a plumose appearance. When the antennæ are short, the palpi furnish distinctive characteristics, they being either four- or five-jointed, whereas the palpi of the succeeding tribes never contain more than three joints, one of which is so much more developed than the others that the organs appear one-jointed.

The insects belonging to this group are numerous and present a considerable variety both of character and habits, and their classification has been variously treated by different authors, some regarding them as constituting a single great family, whilst others divide them into from two to a dozen such groups. We shall here adopt a division into seven families

FAMILY I.—*CULICIDÆ*, OR GNATS.

The Gnats or Mosquitoes may be at once distinguished from all the other *Nemocera* by their long, slender, horny proboscis, which may be half as long as the body of the insect, and is usually

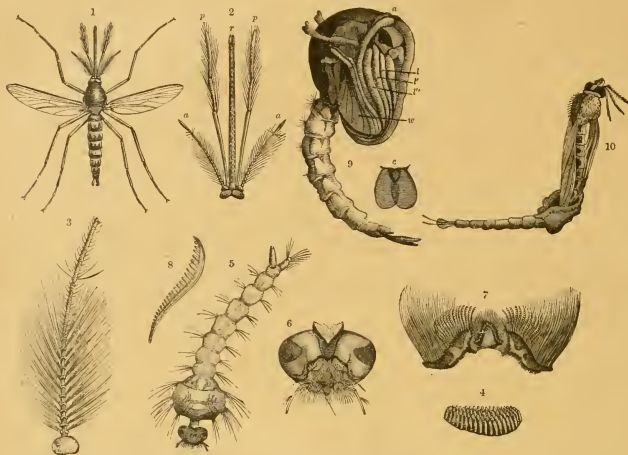
slightly thickened at the tip. This proboscis in the females contains all the parts that are ever found in a Dipterous insect, the bristles representing the mandibles and maxilla being present and free, together with the fifth bristle or epipharynx. The mandibles are wanting in the males. The maxilla have a pair of palpi, of four joints, and comparatively short in the females, of five joints, very long and often more or less hairy in the males. The antennæ are long and slender, composed of fourteen joints, and furnished with whorls of hairs, which become very long and dense in the males, giving them a beautifully feathered appearance. The head is small, and bears a pair of lunate eyes, but no ocelli; the thorax is stout; and the abdomen slender and delicate; the legs are very long and thin, and the veins of the wings are densely clothed with scale-like hairs.

These insects, which are only too well known for their blood-sucking propensities and the intense irritation often produced by their bites, are inhabitants of the water in their preparatory state, and it is accordingly in the neighbourhood of water and in wet seasons that they especially abound. The eggs, which are of an elongated form, are deposited by the female, with the assistance of her hind legs, upon the surface of the water in a small boat-like mass, the eggs being arranged and closely packed together side by side with their pointed end uppermost (Fig. 4, p. 76). From the shape of the eggs, which are a little broader at one end than at the other, the whole mass of eggs necessarily acquires a slight curve like that of a shallow spoon, and the larger ends being downwards, the concavity of the spoon is above, and the little collection of eggs floats securely like a boat upon the surface of the water, until the larvæ are hatched. This soon occurs in favourable weather, and the larvæ descend into the water, where they may be constantly seen during the spring and summer, swimming about with great agility by a violent jerking motion of the body, or suspending themselves from time to time head downwards at the surface of the water, for the purpose of breathing through a curious air-tube, with which they are provided near the tail (Fig. 5, p. 76). This tube springs from the eighth segment of the abdomen, and its apex is surrounded by a circlet of bristles, which, by closing, prevents the entrance of water when the larva is submerged, but opens like a little star when the orifice is brought to the surface of the water, and thus gives free ingress to the air, and at the same time assists in suspending the larva from the surface. The terminal segment of the abdomen, which is beyond the origin of this tube, is fringed with bristles and terminated by five slender, conical plates. The larva has a distinct rounded head, which is furnished with a pair of antennæ, and between these with a pair of jaws fringed with very curious bristles (Figs. 6, 7, 8, p. 76). The latter organs create a sort of whirlpool in the water, which serves to convey to the mouth of the insect the floating particles of more or less nutritive matter that come within its reach. These curious larvæ change their skin three times, and then become converted into pupæ (Fig. 9, p. 76), in which the parts of the perfect insects are rudely indicated; they continue to swim about by the agency of the abdomen, which is terminated by a pair of thin leaf-like organs. In this condition the insects of course no longer take any nourishment, but, like the larvæ, they still suspend themselves at the surface of the water in order to respire air; their position when thus engaged is, however, the reverse of that of the larva, the breathing-organs being now two short tubes, like truncated horns, which spring from the sides of the thoracic region. When the perfect Gnat is ready to emerge the pupa comes to the surface of the water, and remains there quite still, until the skin of its back, which is exposed to the air, dries and splits longitudinally. The perfect insect then slowly emerges, disengaging one part of its body after the other from the pupa-skin, which, during this operation, acts the part of a boat or raft, for the support of its previous inmate, until the wings of the latter have acquired sufficient firmness to enable it to rise into the air. In rough weather these frail boats often prove insufficient, and many Gnats get drowned before their wings are dried (Fig. 10, p. 76).

After their emergence, these delicate creatures, or at least the males, pass their time in a series of aerial dances, in which great swarms of them may often be seen engaged: in fact, so numerous are the insects in certain seasons and localities, that their swarms have sometimes the appearance of great smoke clouds surrounding and ascending from some lofty building, such as the spire of a church. As each female lays about 300 eggs, and the development of the insects occupies only four weeks, it is easy to understand how this extraordinary number of individuals may be produced by the successive generations in the course of the spring and summer, if the external conditions are favourable. The females of the last generation of the season, after fecundation, retire to sheltered

situations, where they pass the winter, coming forth again in the first mild weather of spring to deposit their eggs and continue the species.

As has already been stated, it is only the females (which have all the parts of the mouth developed) that feast upon the blood of vertebrate animals; the males feed only upon the nectar of flowers, to which also the females will resort. They never seem to miss a chance, however, of procuring the more nourishing food, and the irritation caused by their bites is pretty well known to most people. The common English Gnat produces sufficiently disagreeable effects, but the Mosquitoes of warm climates and of high northern latitudes are among the most formidable of insect-plagues, and even in Central Europe the Mosquitoes seem to possess a wonderful power of irritation. Their mode of operation is well described by Professor Westwood:—"Thirsting," he



HOUSE GNAT. (*Culis citraria*.)

1. The male, enlarged. 2. Head of the male, magnified; *a*, antenna; *p*, palps; *r*, proboscis. 3. Antenna of the male still more magnified. 4. Egg floating. 5. Larva, magnified. 6. Head of larva still more magnified. 7. Mandibles and labrum further enlarged. 8. One of the comb-like hairs from the mandible. 9. Side view of pupa, magnified; *a*, case of antenna; *l*, *l'*, *l''*, cases of the limbs; *w*, wing-case; *c*, caudal leaves, front view. 10. Gnat issuing from pupa.

says, "for its evening meal, the little animal enters our apartments, and, instead of whirling, like the Moths, around the light, it betakes itself to its employment, sounding an approach, however, by a tolerably loud humming,* which, in our chambers, at least, is often sufficient to banish sleep. Taking its station upon an uncovered part of the skin, with so light a motion as not to be perceptible when it alights (although it will not hesitate to make its attacks occasionally through our thick clothing), it lowers its rostrum and pierces the skin by means of its exceedingly slender needle-like lancets, which are barbed at the tips, and, as by degrees it pushes these deeper into the skin, the lower lip or sheath, in which they were enclosed when at rest, becomes more and more elbowed towards the breast, until the whole length of the lancets is introduced into the skin. It is supposed that, at the same time, it instils into the wound a venomous liquid, which, while it enables the

* It is only the females that produce this humming or trumpeting noise, and it has been calculated that the wings vibrate 3,000 times in a minute.

blood to flow faster, is the chief cause of the subsequent irritation.^b The insect, when undisturbed, will gorge itself with blood until the abdomen is considerably distended.

The habits of all the insects of this family are so nearly alike that the above description, which applies specially to the common English species, will serve pretty well for them all. Of the typical genus *Culex* there are about nine British species, the commonest of which are the House Gnat (*C. ciliaris*) and the Ring-footed Gnat (*C. annulatus*), both of which frequent houses. The latter is rather the larger, and appears to produce a greater amount of irritation by its bite. The Wood Gnat (*C. nemorosus*) frequents woods and does not come into houses. *Culex pipiens*, with which the commonest British Gnat was formerly identified, is especially an inhabitant of Northern Europe. It was originally described by Linnæus from Lapland, where it abounds in company with other species, some of which occur in Great Britain. Its bite is said to be extremely irritating. The term Mosquito, signifying merely a little fly, is applied in many places to other biting insects than the Culicidæ, but the insects against which travellers have generally to take precautions belong to the present family. Many species have been described from different parts of the world.

FAMILY II.—CHIRONOMIDÆ.

The remainder of the insects forming the first tribe of Diptera, which are frequently united into a single great family, differ from the Gnats in the structure of the proboscis, which is short and fleshy, and has the extremity generally furnished with a pair of fleshy lips, whilst the internal organs are generally reduced in number, or more or less amalgamated with each other and with the proboscis. The eyes are generally rounded or more or less oval, and the ocelli, with very few exceptions, are deficient as in the Culicidæ.

The CHIRONOMIDÆ, which we place as the first family of this group, are more or less Gnat-like insects, with slender antennæ considerably longer than the head, very strongly feathered, especially in the males, in which they usually form two triangular bushes projecting from the front of the head. In the males these organs usually consist of thirteen joints; the females have a smaller number of joints, and their antennæ are usually shorter. The eyes are lunate, and there are no ocelli; the legs are very long and slender, and the tibiæ are not armed with spines; the veins in the wings closely resemble those of the Gnats.

Many of these insects are so Gnat-like that they are very commonly termed Gnats. They resemble the members of the preceding family also in many of their habits, especially in having the larvæ and pupæ aquatic, and in the custom of collecting in great swarms and dancing in the air. They do not, however, in general possess the formidable offensive weapons of the Gnats, and most of them are quite harmless. The best English name for them is that of Midges.

The nearest approach to the true Gnat is made by the genus *Corethra*, one species of which (*C. plumicornis*) is very generally distributed in Britain. It is a small insect, about a quarter of an inch long, of a brown colour, with the antennæ paler and banded with brown, and the feathery hairs of the male antennæ entirely pale; two bands on the sides of the thorax, and the halteres are white. The larva of this species, which may be met with almost everywhere in standing waters, is so beautifully transparent that it can hardly be distinguished from the water in which it swims. It is long and slender, with the thoracic region considerably enlarged; at the extremity of the body there is a delicate fan of hairs which appears to have a respiratory function. The pupa much resembles that of the Gnat, but is straighter, and has the respiratory appendages of the thorax pointed.

The genus *Chironomus*, which gives its name to the family, includes an immense number of species: one hundred and ninety-five are recorded by Mr. Walker as inhabitants of Britain. The commonest of all is *Chironomus plumosus*, a larger insect than the preceding, measuring from one-third to half an inch in length, of a pale brownish-yellow colour, with three blackish stripes on the thorax, the palpi and antennæ black, and the abdomen blackish-grey, with a white band on the hind margin of each segment. The larva, which



CHIRONOMUS PLUMOSUS.

A, head magnified, showing the antennæ, the proboscis (c), and the palpi (p).

abounds almost everywhere in stagnant water, is worm-like and of a blood-red colour; it is, in fact, the animal known to anglers as a bait under the name of the "Bloodworm." The pupa resides in the water, and has five long pilose branchial filaments on each side of the thorax, and the extremity of the body terminated by a long pencil of hairs.

Ceratopogon is another extensive genus of which about eighty European species are known. They also have beautifully feathered antennæ, but the mouth is more perfectly developed than in the rest of the family, the epipharynx and maxillæ being free, pointed, lancet-like organs, with which the females of some of the species are able to draw blood. They are generally very minute. The larvæ exhibit a considerable variety of habits, some living in the ground, some in water, and some under the bark of dead trees. This is the case with the commonest British species (*C. bipunctatus*), a little creature not more than a twelfth of an inch long, of a pithy colour, with a clothing of yellowish hairs upon the thorax, and a white dot upon the fore margin of each of the transparent wings. The body of the larva is cylindrical, slightly thickened in front, and each segment is furnished on the back with two clubbed bristles; the pupa is shorter, much broader in front, and has its abdomen partly encased in the cast skin of the larva.

FAMILY III.—TIPULIDÆ.

This family includes the largest species of the tribe, and, indeed, some of the largest Diptera. None of them have feathery antennæ like those common in the two preceding families, but these organs are long, or, at any rate, longer than the head, thread-shaped, and generally furnished with short hairs, although in a few species they are pectinated. The number of joints is usually thirteen, but sometimes more. The eyes are rounded or oval, and the ocelli are wanting. The front of the head is usually produced into a sort of beak distinct from the short fleshy proboscis; the palpi are four-jointed, and have the last joint very long and sometimes ringed; the legs and abdomen are long, and the wings have numerous veins, with some cross veins forming cells upon the disc of the wing. The larvæ in general live either in the ground or in rotten wood; and the pupæ, which are found in the same situations, are provided with spines upon the abdominal segments, enabling them to push their way out into the air when the perfect insect is about to emerge. The preparatory states of a few species are, however, passed in the water.

We may take as typical examples of this family the well-known insects which are commonly called Daddy Long-legs, or CRANE FLIES (*Tipula*, Pl. 62, A), and may be met with in abundance in meadows during the summer and autumn. The number of species is considerable, about fifty having been described as inhabitants of Europe. The largest of them which is found in Britain is the Giant Crane Fly (*Tipula gigantea*), the female of which measures about one inch and a quarter in length. The commonest British species (*T. oleracea*) is rather smaller, the largest females not reaching the length of an inch. The insect is of a hoary brownish colour, with four brown streaks on the back of the thorax, and has the very long legs of a pale brownish-yellow colour, with the thighs, tibiæ, and tarsi blackish towards the end. The female lays a great number (about 300) of small, shining black eggs, which are deposited in or on the ground, by means of an ovipositor composed of several valves, and she may frequently be observed flying over lawns or other grassy ground, and every now and then pushing down her abdomen so as to reach the earth. The larvæ hatched from these eggs, which are commonly known as grubs, and sometimes as "leather-jackets," from the texture of their skin, are soft cylindrical creatures of a dingy greyish or brownish colour, destitute of feet, but furnished with several conical, fleshy appendages at the hinder extremity of the body. When full grown they are from an inch to an inch and a half in length. These larvæ, and probably those of other species of *Tipula* which also live in the ground, feed upon the tender rootlets of grass and other herbage, and also attack young plants. In this way they often do an immense amount of mischief, laying bare large patches of meadow and destroying great quantities of young corn. The change to the pupa state takes place underground, and the pupæ, which are naked, have a pair of respiratory tubes springing from near the head. When about to give birth to the imago, they push themselves, by means of the spines on the segments already mentioned, up to the surface of the ground, from which they finally protrude perpendicularly for a good portion of their length: the pupa case then splits, and the perfect insect emerges. *Tipula hortulana* is common in gardens.

Some nearly allied species, forming the genus *Ctenophora*, have the antennæ very beautifully pectinated in the males, each joint, from the fourth onwards, having either one or two pairs of branches. The *Ctenophore* are more robust insects, and have a more rapid flight than the *Tipule*, and they are generally adorned with brighter colours, principally tawny or ferruginous yellow in combination with black. These insects reside in wooded localities, and their larvæ feed upon rotten wood. The largest and commonest British species is *Ctenophora pectinicornis* (Pl. 62, B), the female of which is nearly an inch long. Its general colour is black, with two yellow streaks on the thorax, and with the abdomen tawny, but with the extremity and a streak down the middle black.

The larvæ of the genus *Trichocera*, three species of which are generally distributed in Britain, also live in decayed wood and in fungi and decaying vegetables. They are much smaller and more delicate than the insects hitherto referred to, and, in fact, are true Midges, which may be distinguished as WINTER MIDGES, from their not only surviving the winter in the perfect state, but also taking advantage of any spell of mild weather to come out and perform the usual Midge-dances in great companies. The commonest species is *T. hiemalis*, which may almost constantly be found in mild weather upon the glass of windows even in large cities.

The family includes many other small and often more or less Midge-like species, the larvæ of most of which live in the earth, or in fungi and rotten wood. Of these the genus *Limnobia* alone possesses over fifty British species. The larva of a European species of that genus (*L. replicata*) is aquatic in its habits, and has its body furnished with numerous long filaments, which appear to be supplied internally with air tubes, and are probably branchial in their function. In the genus *Psychoptera* also, of which two or three species inhabit Britain, the preparatory stages are passed through in the water, the larva being a long, worm-like creature, much narrower towards the posterior end, from which springs a very long and slender tube serving for respiratory purposes, conveying air to a pair of tracheæ which extend through the body, whilst in the pupa a similar delicate air tube originates from the anterior extremity.

FAMILY IV.—MYCETOPHILIDÆ.

The insects of this family, which may be called FUNGUS MIDGES, are of small size, and generally of very delicate structure. They have usually shorter antennæ than the insects of the preceding families, but these organs are longer than the head, slender, simple, and composed of fifteen or sixteen joints; the eyes are round, and there are on the vertex either two or three ocelli; the front of the head is not produced; the palpi are long and four-jointed, but the last joint is not greatly elongated and ringed; the wings have but few veins and no cells on the disc, and the legs are of moderate length with elongated coxæ and the posterior tibiæ spined. In one genus (*Epidymus*) both wings and halteres are deficient.

The perfect Mycetophilidæ are very active insects, generally found in damp situations upon herbage, upon which they run freely and are able to spring by means of their hind legs. The species are numerous and generally Midge-like. They often come into houses, and may be found upon the windows. Although the antennæ are usually short, they are considerably elongated in some genera; in *Bolitophila* and *Macrocera* especially they are very long, in the latter sometimes three times the length of the body.

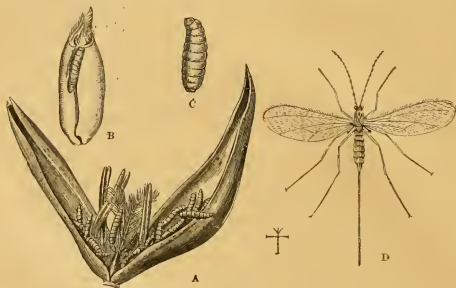
The larvæ generally feed upon fungi of various kinds, but especially upon the *Boleti* which grow upon trees; those of some species, however, are found under the bark of dead trees and about decaying vegetable matter of different kinds. Most of the larvæ, which are slender vermiform creatures, spin a delicate silken web, within which they live, and many of them are gregarious in their habits. The larvæ of *Rhyphus fenestralis*, which may be referred to this family, although regarded as the type of a distinct group by many writers, are very long and slender, and are found to inhabit cow-dung. The larva of *Sciara militaris*, a small black insect with black wings and the lower surface of the abdomen yellow, occurs in enormous abundance in the forests of some parts of Europe, and when about to undergo their change to the pupa state collect in immense numbers and travel together in a compact body, forming a band on the ground some three or four inches broad. From the compact order in which they advance they have received the name of the ARMY-WORM (*Heerwurm*), and their trains have been observed as much as twelve feet long.

FAMILY V.—CECIDOMYIDÆ.

The Cecidomyidæ, or GALL MIDGES, constitute the last family of Gnat-like Diptera, and are indeed the most frail and delicate of all. They have a slender and elongated form; very long, necklace-like antennæ, composed of not less than thirteen joints, but usually of many more, in some cases as many as thirty-six, and each joint bears a circle of short hairs; very long, slender legs, of which the tibiæ are not armed with spines, and the first joint of the tarsi is minute; and wings with very few simple veins. The eyes are lunate or notched in front towards the insertion of the antennæ. There are no ocelli; and the palpi are four-jointed and of moderate length. The females usually have a long ovipositor.

The larvæ of these elegant little insects feed upon various species of plants, generally in gall-like excrescences or distortions of the parts inhabited by them, and the different species attack different parts of the plants they infest; and in all these respects, as Professor Westwood suggests, as well as in their generally minute size and comparatively veinless wings, these insects present a striking analogy to the true Hymenopterous Gall Flies. The larvæ, which are of a stouter and more ovate form than in the preceding families, live within the part of the plant which furnishes their nourishment, which may be the young shoots, the leaves, or even the flowers, and the part thus attacked either swells into a regular gall, or becomes distorted in various ways. The number of species is very considerable, about 100 being recorded as inhabiting Europe. Many of them, by attacking useful plants, frequently do much mischief. Among these may be mentioned especially the HESSIAN FLY (*Cecidomyia destructor*), which has done so much damage to the grain-crops in the United States of America, and received its vernacular name from a belief that it was introduced into the States with the baggage brought by Hessian troops in the pay of the English Government about the year 1776, for which, however, there appears to be no foundation. This redoubtable fly averages rather more than an eighth of an inch in length, and is of a black colour, with some parts, such as the under surface of the abdomen, red. The female has a well-developed ovipositor. The flies begin to make their appearance in April, and continue emerging for four or five weeks. After pairing, the female sets to work to deposit her eggs, which number from 80 to 100, placing them singly, or two or three together, upon the leaves of the wheat-plants. The larvæ are soon hatched out, when they make their way down the leaf and take up their abode within its sheath. Eight or nine larvæ may be found associated in this situation, and their effect upon the plant is to weaken the haulm, so that in the first place the ear is not so well nourished as it should be; and in the second, when the ear is filled out the haulm is not

able to bear its weight, but easily gives way under the pressure of the winds. These formidable larvæ seem to a certain extent to combine the characters of the ordinary larva of the Nemocera with those of the maggots of flies. They are virtually headless, but have their stigmata placed upon the sides of the segments of the body. This character is common to the rest of the larvæ of the family, in many species of which we also find another approach to the Athericerous Flies, namely, that they do not cast the larva-skin before passing to



A, LARVÆ OF WHEAT MIDGE (*Cecidomyia tritici*) IN FLOWER OF WHEAT; B, LARVA ATTACHED TO GRAIN OF WHEAT; C, LARVA; D, PERFECT INSECT.

the pupa state. Hence the pupæ of the Hessian Fly are known as the "flax-seed state" of the insect. The perfect insects of the first brood emerge about the end of August, and these deposit their eggs

upon young plants of winter wheat. The larvæ arrive at maturity and change to the pupa before winter, which season they pass in the latter state. The Hessian Fly has made its appearance of late years in Posen and other parts of Germany.

The WHEAT MIDGE (*Cecidomyia tritici*) is an enemy of the wheat crops in England, and sometimes does much damage. This little plague, however, attacks a very different part of the plant from the Hessian Fly, the female, by means of her long ovipositor, introducing her eggs into the heart of the blossom, sometimes to the number of twenty together. The larvæ, which are of a yellow or orange colour, are known by the name of the "Red Maggot," and seem to attack the central organs of the flower, injuring them so that the seeds are unable to arrive at their full development. It was formerly supposed that they fed upon the pollen, but this does not appear to be the case. When full grown the larvæ go down to the ground, where they undergo their change to the pupa state. The perfect insect, which is about a tenth of an inch long, is of a yellow or orange colour, with black eyes. A second Wheat Midge is recorded as occurring in Britain under the name of *Lasioptera obfuscatæ*. The perfect insect is of a black colour; but the larvæ and pupa are exactly like those of *C. tritici*, and the habits of the two insects are identical.

Of the actual galls produced by these insects the most striking form, and one of the best known, is that formed upon several species of willow. The fly attacks the terminal shoots, which are then stunted in their development, and are so changed in character as to make a flower-like body, compared to a rose by some of the older writers, who regarded the willows thus affected as a peculiar species, which they denominated the rose-willow. The insect producing this gall was even



CECIDOMYID WITH VIVIPAROUS LARVA.

A, Adult Insect; a, B, Pupa; c, Larva, showing young larvæ: a a

described under the name of *Cecidomyia rosaria*. A somewhat similar gall is produced by *Cecidomyia cratagi* and *circumdatus* upon the hawthorn. Another species (*C. veronica*) lives in hairy, gall-like bodies on the germander speedwell. *C. salicis* forms woody galls on the twigs of willows, and *C. bursaria* resides in pyramidal hairy galls on the leaves of the common ground-ivy.

In 1860 a remarkable circumstance in the history of the Cecidomyidæ was discovered by a Russian naturalist, Dr. Nicolas Wagner, at that time Professor in the University of Kasan. He found that certain Cecidomyian larvæ living under the bark of trees develop within them organs analogous or homologous with ovaries, in the chambers of which young larvæ are produced, and these, after remaining for a time free in the general cavity of the parent larva, living and increasing at its expense, at last break out of it, leaving nothing but the empty skin. These young larvæ then produce other larvæ in the same curious fashion, and one generation succeeds another throughout the autumn, winter, and spring. In the summer the last generation undergoes a change to the pupa state, and from the pupa perfect males and females emerge; the latter, after impregnation, deposit a small number of eggs in the bark of trees, the larvæ produced from which commence a fresh series of agamic broods. These species have been referred to a distinct genus named *Miastor*.

FAMILY VI.—PSYCHODIDÆ.

This family includes only a few curious little insects very nearly allied to the preceding, and, indeed, they are often placed with the Cecidomyiæ. They are little moth-like creatures, with broad, deflexed, oval wings, and both wings and body thickly covered with hairs. In the structure of the antennæ they agree with the Cecidomyiæ, but the body and legs are shorter and stouter than in the insects of that family, and the wings are not only very broad, but have the veins, although not much branched, tolerably numerous.

The best-known species is *Psychoda phenoides*, a common British insect, about a tenth of an inch long, with brownish-grey wings, which it carries divergently, as it runs about upon the surface of walls and window panes. It might easily be mistaken for a minute Moth. The larva lives in manure-heaps and among decaying vegetable matter, and is of an elongated form, with a slender, straight, cylindrical, horny tail; and the pupa has two short appendages just behind the head, in the same position as the breathing tubes of the pupa of the Gnat. Another rather larger British species (*P. sexpunctata*) has the wings rather elegantly marked with dark brown clouds or bands, and with black marginal spots.

FAMILY VII.—BIBIONIDÆ.

This last family of the Nemocerous Diptera includes a number of fly-like species; in fact, they are the division "Musciformia" of some writers. They have the body and legs considerably shorter and stouter than the species of the other families; the antennæ short, seldom longer than the head, but composed of from eight to twelve joints; the wings large, with abundance of veins, but with few closed cells. The palpi are generally four-jointed; the eyes are rounded, and in the males generally occupy nearly the whole surface of the head; and in most of them there are three ocelli.



BIBIO MARCI (MALE).

The typical Bibionidæ, including the genus *Bibio* and its immediate allies, are sometimes called "Garden Flies;" they are usually black and hairy, but often with some parts of a lighter colour, especially on the limbs; and they are commonly met with on flowers in fields and gardens, particularly in the spring and early summer. The females frequently differ in colour from the males. Thus in *Bibio hortulanus*, a common British species, the male is black, clothed with whitish hairs; while the female is reddish-yellow, with the head, scutellum, and legs alone black, and the wings in the two sexes differ in coloration. In another abundant species (*Bibio marci*), so called from its appearing about St. Mark's Day, the male has

white wings and the female brown ones. Both sexes of this species are black, and clothed with black hairs. These insects fly heavily, and are sluggish in their general movements.

The females lay their eggs in the ground or in manure-heaps, and the larvæ feed either upon decomposing animal and vegetable matter, or, in some cases, upon the roots of plants, which they are said occasionally to injure considerably. These larvæ are cylindrical worms with ten stigmata along each side; they are furnished with numerous short hairs, which appear to assist them in progression. The minute larvæ of the species of *Scatopse* live in excrements. When full grown, the larvæ of the ordinary Bibionidæ make smooth oval cells in the ground, not far from the surface, and there in the spring they change to the pupa state, in which the insect remains for about a fortnight and then comes forth, the females preceding the males by about a week. The pupa is naked.

In the genus *Simulium*, which may be referred to this family, although separated from it by some entomologists, all the parts of the mouth are fully developed, as in the Gnats, although the proboscis is much shorter, and the insects are able to inflict very severe wounds with these natural weapons. Among the Mosquitoes of South America at least one species of this genus is included; under the name of "Sand Flies" they are well-known plagues in many parts of North America. In Lapland, and other northern regions, they co-operate with the Gnats in tormenting the inhabitants, and even in England they often bite people very severely. But the most formidable

of them would appear to be the *Columbatsch Fly* (*Simulium columbatschense*), which inhabits parts of Hungary and of the regions bordering the whole lower course of the Danube, occurring in swarms, and attacking both men and cattle so vigorously that the latter, at any rate, often succumb to the injuries inflicted by their seemingly insignificant assailants. The transformations of these insects take place in the water. The larva of the common British species (*S. reptans*) is a curious little creature of a cylindrical form, with the body rather thinner in the middle; the head is distinct, and bears a pair of short antennæ, and a pair of singular fan-shaped appendages, the office of which is perhaps respiratory; the thoracic part has a stout retractile tubercle beneath; the end of the abdomen has several curved appendages. This larva lives on the sub-aquatic stems of *Phellandrium* and *Sium*, to which it finally attaches a little cocoon, open above for the reception of the posterior part of the body of the pupa. The latter, which thus sits upright in its cradle, is otherwise naked, but has on each side of the fore part of the thorax eight very long thread-like appendages, which also may be respiratory organs. The perfect insect emerges under water.

TRIBE II.—NOTACANTHA.

Although the character from which the name of this second tribe of Diptera is derived, namely, the presence of spines upon the posterior margin of the scutellum, is not a very important one, the group itself seems to be well founded, having, as already stated, peculiarities of structure and development which would ally it on the one hand with the preceding, and on the other with the following division. It thus stands very naturally between the two groups.

The group is a very well-characterised one. The antennæ, which originate close together on the forehead, apparently consist of three joints; that is to say, the first and second joints are easily recognisable, but the remainder are united in such a manner as to represent a single large joint, which, however, is more or less distinctly ringed. In some forms the apex of the antenna bears a style or bristle. The eyes are large, and there are three ocelli. The proboscis is short, and terminated by fleshy lobes, and within it there are never more than three bristles besides the labrum; but even of these the maxillary pair are often amalgamated with the labium. The legs are simple, and the tarsi furnished with three pulvilli.

The scutellum, as already stated, is usually spinous, but the number of spines is variable; sometimes there are only two, and sometimes four, whilst in a considerable number of species the hinder margin of the scutellum shows a whole row of small spines. Other characters have been already mentioned. These insects constitute only a single family.

FAMILY VIII.—STRATIOMYIDÆ.

The Stratiomyidæ are a tolerably numerous family of flies, well represented in most parts of the world. They may be divided into two subordinate groups, easily recognisable by the number of segments visible in the abdomen.

In the STRATIOMYIDÆ the abdomen exhibits only five free segments. One of the best known species of this group is the *Stratiomys chamaeleon*, a large and handsome fly (see figure on p. 84), rather over half an inch long, and of a general brassy-black colour, clothed with tawny hairs; the scutellum is yellow, and armed with two longish spines; the broad abdomen is black, with two large yellow spots on the first segment and interrupted yellow bands crossing the others; the thighs are black, and the tibiae and tarsi tawny. The transformations of this species are very well known. The female deposits her eggs on the under side of the leaf of some aquatic plant, usually the Water Plantain (*Alisma plantago*), arranging them so as to lie one over the other like tiles on a roof. The larvæ hatched from these eggs are elongated, widest towards the fore part, where there is a small horny head, and much narrowed towards the hinder end, at the extreme point of which the only efficient stigmata are situated, surrounded by a circlet of barbed hairs which, when spread out, enable the insects to suspend themselves at the surface of the water while they breathe. By means of these hairs, when folded in, they can even carry down with them into the water a globule of air, which then looks like a small pearl. These larvæ swim by wriggling movements in which their body is bent into an S-like form. Their food consists of minute aquatic organisms, and particles of nutritive matter, brought to the mouth by the action of a pair of hairy palpi; the mouth is also

furnished with two hooks. The pupa is formed within the mature larva skin, of which, however, it occupies only the wider anterior part, and in this natural "cigar-boat" it floats freely in the water until it arrives at maturity, when the perfect fly escapes through a slit in its protective covering. The flies are found in summer upon flowers near water, and upon the leaves of aquatic plants. The species of *Stratiomys* are numerous in Europe, and some occur in various parts of the world, but



METAMORPHOSES OF *STRATIOMYS CHAMALEON*.

chiefly in the northern hemisphere. Species of several allied genera also pass their preparatory states in the water.

Of the rest, some, such as *Pachygaster ater* and *Clitellaria ephippium*, live as larvæ in rotten wood, and the latter is said to deposit its eggs in the nests of *Formica fuliginosa*. The larvæ of the genus *Chrysomyia*, which includes bright metallic-coloured flies of small or moderate size with an unarmed scutellum, feed upon decaying vegetable matter, and the flies frequent hot-beds; and those of the larger but equally brilliant species of *Sargus* have the same habits, and are to be found in manure and garden mould. The larva of *Sargus cuprarius* is said to attack turnips.

The second group of the family, which may be named *XYLOPHAGIDES*, is characterised by its species having seven or eight free abdominal segments. It includes a few genera, the larvæ of which, so far as is known, live in decaying wood. In Britain this group is chiefly represented by the genus *Beris*, including metallic flies of moderate size, with from four to eight spines on the

scutellum. *Beris clavipes*, *vallata*, and *chalybeata* are common British species. Among the exotic forms of this group are some South American species of gigantic size, some of them measuring an inch and a quarter in length.

TRIBE III.—TANYSTOMA.

This third tribe of the Diptera, which includes a considerable number of families presenting a great variety of structure and habits, is distinguished especially by the structure of the mouth, the proboscis being longer than in the preceding tribe, and sometimes very long, and the internal organs more completely developed. Thus the proboscis generally encloses a lancet-like labrum and at least three other setæ; while in one family the females, at least, present all the parts that we have described as forming the perfect Dipterous mouth. The antennæ consist of only three joints, usually furnished with a terminal bristle, which may be jointed; but in one family the bristle is wanting, and the extremity of the third joint is ringed. They differ from the Notacantha, as also from the following tribe, in the nature of the metamorphosis, the larva skin being cast when the insect passes into the pupa state. The larvæ are worm-like, but furnished with a distinct head, which bears movable claw-like organs appended to the mouth. They generally live underground.

FAMILY IX.—TABANIDÆ, OR BREEZE FLIES.

The insects of this family, which are commonly known as Breeze Flies and Gad Flies, are of a broad, robust form of body, and provided with large and strong wings. They have a broad head, hollowed behind so as to fit close to the thorax, and occupied for the most part by the compound eyes, which in the males generally meet upon the vertex, and in which the upper or middle facets are larger than the rest. They usually have three distinct ocelli. The antennæ are really or apparently three-jointed, but the third joint, which is destitute of a bristle at its apex, and is frequently deeply notched on one side, is usually ringed, either at the apex or throughout. The proboscis is long in the females, shorter in the males, and in the former it encloses the full number of bristles, two of which are deficient in the males. The abdomen is broad, and consists of eight segments; the tarsi have three pulvilli; and the wings have a complete central cell, from which three veins run to the hinder margin.

The Tabanidæ are among the finest and most powerful of the Diptera, and the females make use of the formidable apparatus of lancets with which they are endowed for the purpose of sucking the blood of man and animals. They fly about in the sunshine with a buzzing noise, from which the name of Breeze Flies is said to be derived, and alight quite imperceptibly upon their intended victims. Their bite is exceedingly painful, and their attacks are much dreaded by cattle. The males pass their time more quietly, and are usually found resting upon the stems of trees. Some 500 or 600 species are known from all parts of the world. Many of them are remarkable for the beautiful iridescent colours displayed by their compound eyes.

The preparatory states are passed in the ground, the larvæ, which have a distinct head and consist of twelve segments, feeding, it is believed, upon the roots of grasses and other plants. About the month of May the larva is full grown; it then sheds its skin and becomes converted into a free pupa, having fringes of hairs on the abdominal segments, and a circlet of bristles near the end of the abdomen—structures which are of use to the pupa in making its way out of the ground when about to give birth to the perfect insect. This takes place in the summer, and at this season the Breeze Flies are often a source of great discomfort to both man and beast in many parts of the country. The female of the large Ox Breeze Fly lays some four or five hundred eggs upon grass stems, and the larvæ are hatched from these in ten or twelve days.

In England there are several species which are referred to three genera, but most of them belong to the typical genus, *Tabanus*. The largest of them, and, indeed, one of the largest known species, is the OX BREEZE FLY (*T. bovinus*, see figure on p. 86, and Pl. 62, d), of which the females measure nearly an inch in length; but it is not very abundant in Britain. *Tabanus autumnalis*, one of the commonest species, measures from two-thirds to three-quarters of an inch, and is of a blackish-brown colour, with bronzed brown eyes, and the rest of the head yellowish-white, the antennæ black, the thorax marked with five grey stripes, and the abdomen with five rows of greyish spots. The wings are grey, with a tawny tinge at the base and along the front margin; the halteres are brown with

yellow knobs, and the tibiae yellow with black tips. In another well-known British *Tabanus* (*T. tropicus*) the eyes are of a brassy-green colour, with three purple bands; and in another smaller species, the GOLDEN-EYE (*Chrysops cercutiens*), which is also widely distributed, these organs are of a beautiful golden-green colour, with five spots and the hinder border purple. The most abundant of all the British species is the CLEGG (*Hæmatopota pluvialis*), which is particularly common in low, damp situations, where it is a great plague. This is a dingy, grey-looking insect, with a



METAMORPHOSES OF *TABANUS BOVINUS*.

greyish-brown body, and mottled-grey wings. It is distinguished generically from the *Tabani*, which have antennæ of three joints, with the last deeply notched at the side, and ringed near the tip, by the possession of slender antennæ, in which the third joint is rather long, and followed by three short but apparently distinct joints; it is also destitute of ocelli. The generic name, which may be taken to signify "blood-drinker," is well conferred upon it. In the genus *Pangonia*, several species of which inhabit the continent of Europe, especially in the south, the proboscis is very variable in length, sometimes being more than twice as long as the body.

FAMILY X.—ASILIDÆ.

In these insects, which, from their habits, might very well be called "Hawk Flies," the general form of the body is elongated, and more or less cylindrical, and the head is more rounded and separated

from the thorax, and less occupied by the eyes than in the Tabanidæ. The head is bearded at the sides and beneath. The antennæ show three joints, of which the third is usually simple and long, and terminated by a bristle or style of two joints. The proboscis is generally of moderate length, but strong, horny, and sharp-pointed; it encloses three bristles (besides the labrum), and the upper one, which probably represents the united mandibles, is very strong. The abdomen is elongated, pointed, and generally composed of eight segments; the tarsi have two pulvilli; the wings generally show two complete cells on the disc.

In their habits the Asilidæ are among the most predaceous of their order; but instead of feasting upon the blood of the higher animals, they content themselves with sucking out the fluids of other insects, which they pounce down upon with hawk-like violence, often lying in wait for a passing prey upon fences, walls, and the twigs of trees. Their prey consists largely of Dipterous flies, but they also freely attack insects of other orders; even the hard coats of Beetles and Hymenoptera are not a sufficient defence from the formidable lancets of the Asilidæ, and the larger species of the family are even said to attack and destroy Dragon Flies.

The larvæ are long, depressed, footless grubs, with a scaly head; they live underground, feeding upon the roots of plants and decaying vegetable matter, or in rotten wood; they undergo their transformations in the same situations, and the pupæ have the head armed with spines, and the segments of the abdomen with rows of spinules, which assist the insect in making its way out when the time for its final change has come.

The family probably includes about the same number of species as the preceding one, and they are distributed over the whole surface of the globe. They are generally robust, hairy insects, with strong limbs, and they hold their prey with their fore legs while engaged in sucking out its juices. Many of them, and especially the exotic forms belonging to the genus *Mydas*, inhabiting the tropical parts of America, are of large size; *Mydas giganteus*, a deep black Brazilian species, often measures an inch and three-quarters in length. Even of the European and British species, one of the commonest, namely, the *Asilus crabroniformis*, attains a length of an inch. It is of a tawny yellow colour, with four brown stripes on the thorax, and the basal part of the abdomen black. This insect is said sometimes to attack cattle and other animals. *Leptogaster cylindricus*, a British species, is remarkable for its slender cylindrical abdomen, which is considerably longer than the wings, and in the female is slightly enlarged at the end. It has in consequence some resemblance to the *Tipulæ*, and, like those insects, frequents meadows during the summer.



ASILUS CRABRONIFORMIS.

FAMILY XI.—THEREVIDÆ.

The Therevidæ form a small family of insects, similar to the Asilidæ in the general form of the body, but distinguishable at once by the structure of the proboscis, which is short, not very prominent, and terminated by fleshy lips. The bristles enclosed in it are also much feebler than in the Asilidæ. The antennæ are short, of three joints, and the third joint has a thin style at its extremity; the ocelli are distinct; the abdomen consists of eight segments; the legs are thin, and the tarsi have two pulvilli; and the wings have one complete discoidal cell. The larvæ live in vegetable mould, or in rotten wood, and are exceedingly long and slender, having a small head with a pair of short antennæ, and apparently consisting of about twenty segments, owing to a seeming division of the middle segments. The pupa has the fore part armed with spines, like that of *Asilus*. The species, which are generally of moderate size, are found in most parts of the world, and agree in their general habits with the Asilidæ, although they are more sluggish in their movements, and cannot display so much ferocity in the pursuit of prey. They feed chiefly upon other Diptera, for which they lie in wait in various situations, sometimes on the ground in sandy places, but more frequently upon the leaves and branches of shrubs and trees, and on flowers. The commonest British species is *Thereva plebeia*, an insect rather more than one-third of an

inch long, black, clothed with tawny hairs, with the wings greyish, tawny at the base and along the front margin, the hinder margins of the abdominal segments gilded, and the legs tawny, with the thighs black.

FAMILY XII.—EMPIDÆ.

This is another family of Asiliform Flies, having an elongated body, a pointed abdomen, and a horny proboscis. The head is globular, and the eyes of considerable size, meeting in the middle in the males; the crown of the head is not excavated as in the Asilidæ; the ocelli are distinct; and the antennæ are of three joints, with a long and often jointed style or bristle at the apex. The proboscis, which is horny and destitute of terminal lips, is generally of moderate length, and placed perpendicularly under the head; sometimes, however, it is very long, and is then folded beneath the breast. It contains three bristles, which are much finer than in the Asilidæ. The wings have a single complete cell on the disc. In their transformations the Empidæ resemble the species of the preceding families.

Although much smaller than the Asilidæ, the Empidæ are equally predaceous in their habits, feeding voraciously upon insects of various kinds, but especially upon other Dipterous flies. They may constantly be found flying or running about, carrying with them, transfixed by the bristles of the mouth, insects quite as large as themselves; and in some, forming the genus *Hemerodromia* and its allies, the fore legs are even converted into prehensile organs, the coxæ being as long as the thighs, and the thighs thickened and spinous beneath.

These, and many other species, all of small size, pursue their prey by running rather than on the wing. They are found upon the leaves of shrubs and herbage, and their quickness of foot is expressed in several of the generic names applied to them, such as *Tachydromia* and *Ocydromia*. These insects are characterised by the structure of the antennæ, in which the first joint is so small as to be lost sight of; so that the organs apparently consist of only two joints, with a long bristle either at the apex or on the back of the apical joint.

The number of species in this family is very great, but they are chiefly confined to the temperate or colder regions of the earth. They are very numerous in Europe. In default of insect prey, or to vary their diet, they visit flowers and suck up the honey. Many species frequent the neighbourhood of water, and some, such as the *Hilara*, assemble in great swarms over the surface of a stream and engage in most complicated aerial dances.

The largest species of the family belong to the typical genus *Empis*, the female of one of the best known British forms (*Empis tessellata*) attaining a length of nearly half an inch. This insect is of an ash-grey colour, with three black stripes on the thorax, and the abdomen showing a sort of tessellated pattern. It is common in spring. When paired, the females of this and of many other of the larger species of the family are always found to be busily engaged in sucking out the juices of some other insect. It seems probable that the male seizes the opportunity of his intended partner being thus occupied to make his advances; if her mouth was free he would in all likelihood himself fall a sacrifice to her voracity.

FAMILY XIII.—ACROCERIDÆ.

A few very curious flies constitute this family, the true position of which has often been a puzzle to entomologists. They seem, however, to be most nearly related to the Humble-bee Flies, which form the next family. They have the thorax and abdomen much inflated, the thorax especially being much swelled above, and the head very small and globular, and placed very low down upon the front of the thorax, so that it is more or less concealed when the insect is looked at from above. The eyes are comparatively large, forming the greater part of the surface of the head, but there are usually three distinct ocelli. The three-jointed antennæ are very small; the proboscis either long and thin, and bent under the body, or entirely wanting; the legs short and weak, with three pulvilli to the tarsi; and the halteres concealed beneath large, arched scales. The abdomen has only six segments.

The known species of this family are not numerous. Those possessing a long proboscis are chiefly exotic, but in them this organ is usually longer than the body. Thus *Lasia flavitarsis*, a Brazilian species of a steel-blue colour, with the scutellum and base of the abdomen violet and

the tarsi yellow, measures about half an inch long, and has a proboscis three-quarters of an inch in length. These long-trunked species feed upon the juices of flowers; the labrum is very short, and the three bristles enclosed in the proboscis are thin. Most of the European species are destitute of a proboscis, and apparently take no food after arriving at the perfect state. They are not abundant, and are feeble and slow in their movements, generally passing their time upon leaves and flowers, or sitting upon the trunks and branches of trees, about which they often fly in the bright sunshine. The females deposit their eggs, which are very numerous and black, upon the dried twigs of trees. Scarcely anything is known of their preparatory states, but it is supposed that the larvæ are parasitic in their habits.

FAMILY XIV.—BOMBYLIIDÆ.

The Humble Bee Flies, which are the typical forms of this family, agree, to some extent, with the preceding insects in general form, although they have not the thorax and abdomen so much inflated; but the group includes a number of species which show no such structure of the body. They have rather a small head, with large eyes which usually meet in the male, and three ocelli; the antennæ are of moderate length, of three joints, and well extended in front of the head; the proboscis is long and projected in front of the head, and the bristles contained in it are very delicate; the abdomen consists of six or seven segments; the legs are long and thin, and the tarsi have three pulvilli, of which the middle one is often hair-like; the wings diverge on each side of the body, and there is no scale covering the halteres. The transformations of these insects are somewhat imperfectly known, but the larvæ of many of them are undoubtedly parasitic upon other insects, some attacking the caterpillars of Lepidoptera, while others live in the nests of different species of solitary Bees.

The great majority of the species of the family are exotic, and they occur in all parts of the world. The most extraordinary development of the proboscis occurs in a species from the Cape of Good Hope, *Nemestrina longirostris*, which measures about two-thirds of an inch in length, and has a proboscis nearly three inches long, which it employs in sucking the nectar from the long-tubed flowers of the *gladioli*, &c. The sweet juices of flowers, in fact, constitute the general food of the insects of this family, and in search of it they sweep from flower to flower with a rapidity that shows great strength of wing; and while engaged in probing the recesses of the flowers with their long trunks, they usually hover motionless in the air, like minute Humming-birds. They generally show no brilliancy of colour, shades of brown and black being the prevailing tints. The typical *Bombylii*, which are stout-bodied insects densely clothed with hairs, somewhat like little Humble Bees, are represented in Britain by about four species, out of over a hundred which exist in other parts of the world. Two of them (*Bombylius major* and *B. medius*), which measure a little under half an inch in length, are common in gardens and woods, and on sandy heaths, during the spring and summer. They are both black, and clothed with tawny or yellowish hairs, but the former has transparent wings, with a dark brown stripe starting from the base and running along the anterior margin nearly to the tip of the wing, while the second has greyish wings, with a yellowish-brown band running from the base along the fore border, and beneath it a series of brown spots. In the genus *Anthrax*, species of which are met with in dry places flying over the surface of the ground in the hot sunshine, and resting from time to time, with their wings widely expanded, upon a stone or other projection, the base and fore margin of the wings are usually black, the dark and light parts of the wings generally occupying nearly equal spaces.



BOMBYLIUS MAJOR.

FAMILY XV.—LEPTIDÆ.

The Leptidæ form a very small family allied to the preceding, but having the antennæ very short, composed of three joints, of which the last is bent down, and bears a bristle either at its apex or near its base. The proboscis also differs, being short and thick, and terminating in a pair of fleshy lobes. There are three bristles in the proboscis, and the palpi are long and

prominent, consisting of a short basal and long second joint. In general form the insects are rather slender, with a long abdomen; the legs are slender, with three pulvilli on the tarsi; the wings have one complete cell on the disc.

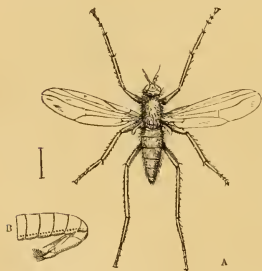
These insects are generally of moderate size, and frequently have the wings spotted. They are found during the summer in meadows, about hedges, and in woods. They are sluggish in their habits, and the larger species are commonly found sitting on the trunks of trees, always with their heads downwards. They sometimes prey upon other insects. The larvæ live in the ground, in sand, manure, and decayed wood; and that of one species (*Leptis vermileo*) is described as making small conical pitfalls in the sand, for the purpose of entrapping small insects, after the fashion of the Ant-lion. The habits of another species (*Atherix ibis*), not uncommon in Britain, are still more curious. The fly, which is about a third of an inch long, is of an ash-grey colour, with transparent wings thickly covered with more or less confluent brown spots. The females are gregarious, and attach their eggs in large pear-shaped clusters to boughs overhanging streams of water. The cluster is formed by the contributions of numerous females, which remain on the spot and die there, and when the larvæ are hatched they fall into the water, which is their future residence.

FAMILY XVI.—DOLICHOPODIDÆ.

This is a numerous family of small flies generally adorned with bright metallic colours, which in some respects seem to form a passage to the next tribe. They have three-jointed antennæ, short or of moderate length, but prominent, and the third joint, which is either oval or pointed, has a bristle springing either from its extremity or its back. The proboscis is short, thick, and fleshy, and contains only one bristle, the maxillæ being united with the labrum, although their palpi, which consist only of a single joint, are of considerable size. The labrum is large and horny. The head is of moderate size; the eyes usually separate in both sexes; the ocelli distinct; the legs long and thin, but often showing very curious developments of certain parts, especially the tarsi, which have three pulvilli, of which the middle one is smaller than the others; and the wings have only five longitudinal veins, with a cross vein uniting the fourth and fifth. The structure of the abdomen in the males is very peculiar. It is composed of six segments, and its apex is bent forward, and furnished with an extraordinary variety of copulatory appendages. The larvæ are long, slender, and cylindrical, and live in the ground or under the decaying bark of trees; they have the last segment thickened, and furnished with two tubercles above, each of which bears a stigma. The pupa is found in the same situations as the larva, and is free, with two curved horns on the thoracic region and rows of bristles upon the segments of the abdomen.

In their habits, notwithstanding the imperfection of their mouths, the Dolichopodidæ are all predaceous; in this respect resembling some of the Empidæ, with which they would seem to have considerable relationship. They are found running about, backward, forward, and sideways, upon the leaves of plants and trees, from which they are said to be fond of licking the honey-dew; and they also frequent the trunks of trees, walls, palings, &c.; but many of them haunt the neighbourhood of water, and seize insects, and even small worms and mollusca, when they come to the shore. Some of them actually venture upon the water in pursuit of prey, running freely upon the surface, after the manner of those curious long-legged Bugs (*Gerris*) whose movements must be familiar to every one. One genus has

received the name of *Hydrophorus* from this circumstance, and they not only frequent the surface of lakes and ponds, but even venture on the sea. These and some others have the fore legs fitted to act as raptorial organs. The prey, when seized, is readily admitted into the gaping orifice at the extremity of the short proboscis, and held fast there while its fluids are being sucked out. Many of the species live in the vicinity of the sea-coast.



A, *DOLICHOPODUS DISCIFER*. B, SIDE VIEW OF THE EXTREMITY OF THE ABDOMEN OF THE MALE.

The species are exceedingly numerous, and they are found in most parts of the world. Over 200 are recorded as inhabiting Europe, and a large proportion of these occur in Britain. A great many have also been described as inhabitants of the United States, but the known species from tropical and southern regions are comparatively few, so that as far as present knowledge goes the family would seem to abound particularly in the temperate and colder parts of the northern hemisphere. Many species are found high up on mountains.

FAMILY XVII.—PLATYPEZIDÆ.

The Platypezide are a very small family of minute Diptera, nearly related to the Dolichopodidæ, but differing from them in the flattened form of the body, the hemispherical shape of the head, which in the males is almost entirely occupied by the eyes, the shortness of the legs, of which the posterior pair are stout, and the presence of six instead of five longitudinal veins in the wings. The number of species is small, and very few are recorded from beyond the European region. Most of the genera are represented in Britain.

The perfect insects, most of which are under one-sixth of an inch in length, are active in their habits, and are generally found in woods and about hedges, although some of them prefer the herbage of marshy localities. Their larvæ live in fungi, and are broad and rather flattened, with stiff bristles along their margins. These insects, like the preceding, seem to lead towards the next tribe.

FAMILY XVIII.—SCENOPINIDÆ.

A few very small flies, which seem to have some affinity to the Therevidæ, have been formed into a separate family under the above name. They have short antennæ, with three joints, of which the third is the longest, blunt at the tip, and without any bristle; a very short, fleshy proboscis, terminated by broad lobes, but with only a single enclosed bristle; short legs; and wings with a complete cell on the disc. These insects also lead in the direction of the next tribe, but their long slender larvæ, which live in fungi, cast their skin on passing to the pupa state, and in other characters, such as the venation of the wings, they rather resemble the central types of the Tanystoma. *Scenopinus fenestralis*, a small fly rather more than a sixth of an inch long, receives its specific name from its being common on windows, especially those of stables; it is also found on the leaves of plants and about walls. It is black, with reddish tawny legs. Another common species in similar situations (*S. fasciatus*) is entirely black except the tarsi, which are reddish.

TRIBE IV.—ATHERICERA.

As already indicated, some families of the preceding tribe show an evident transition towards the present one, but in all cases the character of the metamorphosis serves to turn the scale. In all the Tanystoma the larva skin is cast when the insect passes into the pupa state; in all the Athericera the transformation takes place within the skin of the larva, which hardens into an oval case, serving efficiently as a protection to the helpless inmate. The antennæ throughout the tribe consist of only two or three joints, of which the third is never ringed, but generally furnished with a style or bristle, which may spring either from its extremity or from its back. The proboscis is sometimes quite rudimentary, but is generally a more or less fleshy or membranous organ, with very distinct terminal lobes; it is always elbowed at a short distance from its base, and in most cases can be retracted within the cavity of the mouth, which is situated on the lower surface of the head. The palpi, which consist of a single joint, are attached to the sides of the proboscis a little above the bend, so that when the proboscis is withdrawn they are entirely concealed. In one family of the tribe the proboscis encloses three lancets besides the labrum; in the remainder only one.

The larvæ are soft, fleshy, footless grubs, distinctly segmented, narrowed, and usually pointed in front, but without anything that can be distinguished as a head. The mouth is furnished with one or two hook-like organs, and usually with fleshy lobes, and with a kind of tongue. The posterior end of the body generally terminates bluntly, and is in many cases cut off quite flat. Upon the surface of the last segment we find a pair of stigmata, which are the sole breathing apertures of the larva. In general terms, we may say that most of the larvæ of this tribe are *maggots*. A few aquatic larvæ are provided with breathing tubes.

On passing to the pupa state the larva skin contracts more or less, and generally becomes much shorter, at the same time that the two ends of the body become equally rounded, and thus the whole assumes an oval form. Even the traces of the segments become much fainter, or almost unrecognisable; but in many the line marking off the lid, which will be thrown off for the escape of the perfect insect, is to be seen distinctly towards the anterior end of the case. At first the enclosed insect detaches itself from the larva skin, and thus forms a soft, more or less pulpy, shapeless mass, on the surface of which, by degrees, the rudiments of the parts of the perfect insect make their appearance. When mature the fly throws off the lid of its case by the action of the head, which commonly acquires a sort of temporary bladder-like inflation for this purpose (see figure on p. 72).

FAMILY XIX.—SYRPHIDÆ.

Although the insects of this tribe present an almost infinite variety of structure, they are usually divided only into two great families, which are very distinctly characterised. The Syrphidæ form a family of tolerably uniform character, and it is in the second of the two groups that the great variety is displayed, although the whole are united by certain peculiarities, and the subordinate types melt into one another.



WING OF SYRPHUS.

The Syrphidæ may always be recognised by a very obvious though apparently unimportant character, namely, the presence in each wing of a peculiar false vein, intersecting the short cross vein between the third and fourth longitudinal veins. The longitudinal veins themselves do not generally reach the margin of the wing, but terminate in fine veins which unite them, and usually run parallel to the margin, cutting off a narrow border. The antennæ are three-jointed, with an apical or dorsal bristle, which is in some genera beautifully feathered; the eyes are large, meeting in the males; the ocelli are three in number; the proboscis usually short, with fleshy end-lobes, and enclosing three bristles besides the labrum, the maxillæ being free; the palpi are formed of a single joint, and are not prominent; the abdomen consists of five segments, and is flattened, and occupied, to a great extent, by air sacs; and the tarsi have two pulvilli.

This family consists for the most part of elegant, brightly-coloured flies, remarkable for their rapid flight, and for the ease with which they hover in the air over flowers. During flight many of them produce a loud piping or buzzing sound. They are of moderate or considerable size, and occur abundantly in all parts of the world. The surface is sometimes naked and shining, sometimes hairy, and in the latter case the insects have a bee-like appearance. They are constantly seen about flowers, upon the juices of which they feed, and are particularly partial to the flowers of the Compositæ. Notwithstanding the uniformity of the characters and habits of the perfect insects, the larvæ exhibit a considerable diversity in both respects. Some of them are aquatic in their habits; but the majority live out of the water, some feeding upon the roots and bulbs of plants, others living in decaying wood, in mud, and even in sewers, others again being parasitic in the cells of Wasps and Humble Bees, while a considerable number crawl over the leaves and shoots of plants, and co-operate with the larvæ of the Neuropterous Hemerobiidæ in the destruction of Aphides.

The last-mentioned habit is displayed by the larvæ of the typical genus *Syrphus* and its allies. These are the prettily banded flies which may be seen everywhere in gardens and in the open country throughout the summer, often hovering motionless for a considerable time over some object, such as a flower, but darting off with remarkable rapidity when disturbed, and often returning again and again to the same spot. There are some thirty British species of the genus *Syrphus*, and most of them are abundant and widely distributed. One of the commonest is the *Syrphus pyrastræi*, an insect about half an inch long, of a blue-black colour, with a stripe on each side of the thorax and the scutellum tawny, and three whitish or yellowish bands, interrupted in the middle, upon the abdomen. The wings, as is usual in these flies, are colourless and transparent; the halteres are yellowish, and the legs are yellowish, with the thighs more or less black. By many people these harmless flies are mistaken for wasps, and some of the allied species are particularly wasp-like.



SYRPHUS PYRASTRÆI (A), LARVA (B), AND PUPA (C).

Their larvæ, which are footless grubs, generally much wrinkled across, live upon the leaves and twigs of plants which are infested by Aphides, in pursuit of which they crawl along upon their flattened under surface in a manner which somewhat reminds one of the movements of a common slug. They are narrowed in front, and have no distinct head, but the mouth is furnished with a sort of trident with which the larvæ transfix the Aphides and suck out their fluids. When full grown the change to the pupa takes place within the larva skin, which remains attached to a leaf or twig, and hardens in the usual way. As the parent flies always lay their eggs singly in the midst of colonies of Aphides, the larva when hatched has of course an abundant supply of food at its command; its growth is in consequence rapid, and there are several broods of the flies in the course of the summer. By their destruction of Aphides they must be regarded as conferring an important benefit upon the farmer and gardener.

The *Tolucella* (see Pl. 62, r), which are nearly related to the *Syrphi*, but are of a stouter form of body, and less gaily coloured, reside in the larva state parasitically in the nests of Wasps and Humble Bees, and sometimes they mimic the appearance of the insects in whose dwellings they are unbidden guests in a most remarkable manner. This is especially the case with a common British species (*Tolucella bombylans*), which infests the nests of Humble Bees; it is black and hairy, precisely resembling a small Humble Bee, about half an inch long, and, curiously enough, it even varies in the colour of the hair on certain parts of the body, and this very much as in different species of Bees. The larva has the body much wrinkled, and along each side a double row of short spines, while four or six longer spines radiate from the broad and rounded hinder extremity; and below there are six pairs of tubercles, each with three claws, which may be regarded as prolegs. These larvæ feed upon those of the *Bombi* and Wasps whose nests they frequent.

A considerable number of the species, however, appear to feed on vegetable matters, either fresh or in state of decay; the larvæ of several species feed on the bulbs of plants (some on those of *Narcissus*); others, forming several genera, live among rotten wood. Of this number are many species of the genus *Eristalis*, but that group includes one species with an aquatic larva. It is a stout, pitchy black, hairy fly, over half an inch long, with the scutellum, the hind borders of the abdominal segments, and a triangular spot on each side of the base of the abdomen tawny; it is met with abundantly everywhere in gardens and fields. The larva is a most singular creature, having a somewhat ovate segmented body, furnished beneath with seven pairs of tubercles armed with hooks, and terminated posteriorly with a long tail composed of two segments, one of which slides within the other after the fashion of the joints of a telescope. This tail enables the larva to communicate with the air for respiratory purposes when it is lying snugly concealed in the mud at the bottom of some piece of stagnant water, which is the regular habit of the insect in this stage. When full grown the larva quits the water and buries itself in the ground, where the pupa is formed in the usual way within the larva skin. These larvæ are commonly known as "rat-tailed larvæ." Their skins are exceedingly tough, and in allusion to this the species is named *Eristalis tenax*. *Helophilus pendulus*, a nearly allied species, has a similar larva, with similar habits.



ERISTALIS TENAX AND ITS RAT-TAILED LARVA.

FAMILY XX.—MUSCIDÆ.

The remainder of the *Athericera* are generally regarded as forming a single great family, of which the genus containing the common House Fly (*Musca domestica*) may be taken as the type. The members of this family are, as already stated, very variable in their character. They have three-jointed antennæ, and these, except in one genus (*Conops*) which shows a strong relationship in other respects to the *Syrphidæ*, are short, have the third joint usually the largest and furnished with a bristle springing from its back, and are commonly bent down in front of the face. The proboscis has fleshy terminal lobes, and encloses only a single bristle besides the labrum; the palpi generally project

and consist of one joint; the wings show no trace of the false vein which characterizes the Syrphidæ; the tarsi have two pulvilli; and the abdomen consists of five segments. There is no doubt that this is not only the most varied but also the most extensive family of the Diptera. It includes some thousands of species distributed over all parts of the world, and the species are probably nearly as



CONOPS FLAVIPES.

numerous as those of all other families of the order taken together. Of such a multitude it is scarcely possible to make any general statements, but it may be remarked that of many species the individuals are excessively numerous, and that in consequence their influence for good or for evil is very great. The larvæ are for the most part of the kind known in common parlance as "maggots," and they present a great variety of habits. Many are parasitic not only on other insects, but even on vertebrate animals; others reside in living plants, and feed upon their substance; others again seek dead and decomposing animal and vegetable matter and even the excrements of animals; whilst a few are found in water. Of the latter the most remarkable are the *Ephydræ*, several of which occur in salt water, and even in the condensed brine of salt works. These have a long breathing tube something after the fashion of the rat-tailed larva of *Eristalis tenax*. The number of species whose habits render them directly injurious to man and his possessions is not very great when compared with that of those whose action in the economy of nature must be regarded as beneficial, such as the parasites upon the larvæ of injurious insects and the consumers of carrion and other impurities.

In the exceptional genus *Conops*, already referred to, the antennæ spring from a projection of the forehead, and are prominent and longer than the head; their first joint is short, the second very long and thickened towards the apex, and the third short, stout, and conical, with a short, jointed style at the apex. They are handsome flies, generally black, banded with yellow, and frequent flowers after the manner of the Syrphidæ. Their larvæ are parasitic in Bees, Wasps, and Grasshoppers.

Another group of parasitic Muscidæ consists of the great genus *Tachina* and its allies, forming the sub-family TACHINARIE. These have the scales behind the base of the wings very large, entirely concealing the halteres, and the bristles projecting from the third joint of the antennæ either entirely naked, or hairy or plumose only at the base. Of this group there are several hundred species in Europe alone, and they are abundant in all parts of the world. In the larva state they are parasitic upon other insects of various orders, chiefly, however, the caterpillars of the Lepidoptera, although Beetles, Field Bugs, Earwigs, Grasshoppers, and other Orthoptera, and the larvæ of Saw Flies, are commonly attacked by them, and some species live in the nests of Bees and Wasps, while others even attack Spiders. The flies themselves are generally moderately stout and rather roughly hairy. They fly with great rapidity. One of the largest and finest species, which is abundant in many parts of Europe, and not uncommon in Britain, is the *Tachina grossa* (see Pl. 62, κ), which measures two-thirds of an inch in length, and is of a black colour, clothed with bristles rather than hairs, and with the head and base of the wings reddish-yellow. The antennæ in this insect are of peculiar structure; they have the second joint much longer than the third, which is broad and somewhat quadrangular.

Gymnosoma rotundata is distinguished from the rest of the group by its inflated, nearly spherical abdomen and the absence of the strong hairs which most of them possess. It is rather more than a quarter of an inch long, black, with the abdomen yellowish-red, banded and spotted with black. The larva of this insect is parasitic upon a Field Bug (*Rhaphigaster punctipennis*). In *Prosenia siberita* the proboscis is very long and slender, and the bristle of the antennæ is feathered, thus indicating a transition towards the next group. Many of the exotic species are adorned with beautiful colours. One of the finest is the Australian *Rutilia splendida*, which has the upper surface adorned with golden green spots, with blue superficial reflections.

The MUSCARIE form a second group having the halteres concealed by the wing scales, but in them these organs are generally smaller than in the Tachinarie, and the bristles of the antennæ are feathery or hairy to the apex. This group includes the commonest and best known species of the family, such as the Common House Fly (*Musca domestica*) and the Bluebottle (*Musca vomitoria*). The larvæ live either upon dead flesh or excrements, and the attacks of some of them upon meat

during the summer are only too familiar to housewives. The larvæ of the common Fly reside in excrements of all kinds, and consequently the insects abound especially where such substances are allowed to accumulate, as in the neighbourhood of stables, &c. The flesh-eating species are tolerably numerous, and most of them are viviparous, depositing living larvæ, which are hatched in the oviducts, upon dead animal substances of all kinds. The ovarian organs are of large size, and the female of *Sarcophaga carnaria* may produce as many as 20,000 young larvæ, and thus one cannot be surprised at the influence these seemingly insignificant animals have in the removal of carrion. The Flesh Fly (*Sarcophaga carnaria*), one of the largest of our species, is about half an inch long, black, with six greyish-white streaks upon the thorax, and four rows of square white spots upon the abdomen. Under the term Bluebottle at least two species are included, namely, *Musca vomitoria* and *M. erythrocephala*. They both have the under surface of the head red, but in the former this part is clothed with reddish and in the latter with black hairs. There are also two abundant species of so-called Greenbottle Flies (*Musca caesar* and *M. cornicina*), remarkable for their beautiful golden-green or bluish-green colour, but distinguishable by the palpi being tawny in the former, black in the latter. There are many other species, and all have the same scavenger-like functions to perform in the economy of nature. Occasionally, however, these larvæ become directly injurious to man, by getting introduced into the stomach with food, or by attacking sores and other open wounds. In the latter way they also frequently plague domestic and other animals.



MUSCA VOMITORIA.

A fly closely resembling the common House Fly is the *Stomoxys calcitrans*, which, however, is furnished with a long, slender, projecting proboscis, by means of which it pierces the skin and sucks the blood of man and other animals. A still more formidable species is the Tsetse Fly (*Glossina morsitans*) of tropical Africa, of which such terrible accounts have been given to us by travellers in those regions. The Tsetse, which inhabits certain parts of Central Africa, bites cattle so severely as to injure them greatly, causing them to fall into a diseased state and finally die; in fact, the action of this fly is said to be so pernicious as to render the zones which it inhabits impassable barriers to man and domestic cattle.



TSETSE FLY.

An immense number of species of Muscidæ have the halteres uncovered, the wing scales being either absent or greatly reduced in size. The group formed by them has in consequence received the name of ACALYPTERÆ. In other respects they exhibit considerable differences both of structure and habit.

The larvæ of a considerable number live in excrements, and one of the most abundant of these is a dingy yellow-looking fly, about a third of an inch long, which may be met with during the greater part of the year, flying about and alighting upon manure heaps in the fields and elsewhere. This insect is very appropriately denominated *Scatophaga stercoraria*, both generic and specific name serving to indicate the unsavoury nature of its haunts. Its eggs are deposited in dung, as moisture is necessary for their development, but in order that the young larva may not be smothered on its emergence from the egg, the latter is not wholly immersed, but is prevented from sinking by two divergent horns springing from its upper end. The perfect insect preys on other Diptera. The *Anthomyia*, which are exceedingly numerous, over 200 European species being recorded, are nearly related to the preceding, and, like them, deposit their eggs in excrementitious matter. Except when engaged in oviposition, however, the perfect flies generally frequent flowers, as, indeed, is expressed in their generic name. They are common frequenters of our gardens. One of the most abundant

species (*Anthomyia lardaria*), resembles the Flesh Fly in size and general appearance, having the thorax streaked and the abdomen tessellated in much the same way.

In the genus *Ephydra* and its allies the larvæ are aquatic in their habits, generally residing either in the semi-fluid green matter that is so commonly seen on the surface of stagnant water, or in the mud at the bottom of shallow pools. In general these larvæ possess respiratory tubes. Some of them, as already mentioned, live in salt water, either on the sea-coast or in the pools of salt marshes, whilst some have been found in strong brine. The perfect insects frequent the shores of the pools in which the larvæ reside, and appear to feed chiefly upon other insects. *Ochthera mantis* has the forelegs greatly developed, the coxæ long, thighs very stout, and the tibiæ curved, so as to form a raptorial limb. It is found commonly upon sandy shores.

The numerous species of the genera *Ortalis* and *Trypeta* deposit their eggs upon living plants, within the substance of which the larvæ afterwards feed, often producing gill-like excrescences. They are generally small flies, and have the wings either transparent with dark spots, or of a dark colour with transparent spots, and as they walk about they keep these organs in constant tremulous motion. They are particularly attached to the Compositæ. *Dacus oleæ*, a species of a nearly allied genus, chiefly represented in the tropics, attacks the olive. The larva feeds at first upon the leaves, but afterwards upon the pulp of the fruit, which it often seriously injures. It is known in Provence under the name of "Chiron." The genus *Chlorops* includes a number of small and delicate species, the larvæ of which reside in living plants, and are especially attached to the Gramineæ. They reside within the stems of the plants, feeding upon the interior substance, and thus prevent the formation of seed by intercepting the supply of material. In this way several of the



CHLOROPS TENIOPUS.

species are exceedingly injurious to corn crops, notwithstanding their minute size, which rarely exceeds an eighth of an inch. They are generally yellow, prettily streaked on the thorax, and banded on the abdomen with black (*Chlorops lineatus* and *C. teniopus*).

The PHORIDES constitute a small group which has been regarded as a distinct family by many writers. They are distinguished by having only three longitudinal veins with no cross vein in the wings, and the antennæ placed quite low down towards the mouth, and exceedingly short. The species, which are not numerous, are all of small size, and their larvæ feed upon fungi and decaying vegetable matters.

The (ESTRIDÆ, forming the last sub-family of the Muscidæ, are all parasitic in the larva state, and are the "Bot Flies" only too well known to farmers. They have very short, wart-like antennæ, which are sunk into cavities of the forehead, from which nothing more than the apical bristle projects, and the proboscis is quite rudimentary. The species show three different modes of parasitism, but all devote their attention solely to mammals.

Those of the genus *Estrus* lay their eggs upon the hides especially of cattle and deer, and the larvæ, when hatched, make their way under the skin and there take up their abode, producing large and painful swellings, with an opening at the summit, where the hinder extremity of the larva remains in communication with the air for the purpose of respiration. The best-known species is parasitic on our domestic cattle (*Estrus* or *Hypoderma bovis*), and is particularly partial to young steers. The abdomen of the female has a sort of telescopic termination, which is instrumental in attaching the eggs to the skin of the ox. The cattle are so well aware of the danger attending the presence of the insect, that as soon as it appears near them, the whole herd exhibit the most unmistakable signs of terror, rushing about their pasture with their tails in the air, and in case of need taking refuge in the water, where the fly will not follow them. Several other species are known; one of them (*E. actæon*) attacks the Red Deer, and another (*E. tarandi*) the Reindeer. Those of the allied genus *Cuterebra* deposit their eggs upon the skin of Hares and other rodents.

The *Cephalomyia* choose another part of the animal for the reception of their larvæ, which are sometimes produced alive. They introduce their eggs or larvæ into the nostrils of the unfortunate animals on which they are to live, and the larvæ then make their way into the frontal and maxillary

cavities, where they adhere to the mucous membranes by means of the hooks with which their mouths are provided. The larva of the best-known species (*Cephalomyia ovis*) infests the Sheep, and is described as sometimes making its way into the brain, and causing vertigo and finally the death of the animal. The Sheep show their recognition of their enemy very plainly when the fly comes near them, by shaking their heads and stamping on the ground, or, as a last resource, getting into dry, dusty spots, and crowding together with their noses to the ground. The larvæ, when full grown, escape again through the nostrils, and fall to the ground, where they become pupæ. A large species (*C. auribarbis*), which is parasitic on the Red Deer in Germany, is described as shooting its young larvæ into the nostrils of its victim without alighting. The Reindeer has also its peculiar plague of this kind (*C. trompe*).

The larvæ of the species of *Gastrophilus* harbour in the stomachs of various herbivorous mammals, but especially of Horses, in which they are well known as "bots." The female of course is unable to introduce her offspring directly into the stomach of the animal on which it is to be parasitic, but she attaches her eggs to the hairs of those parts which are easily reached by the tongue, and indeed are habitually licked. The warmth and moisture of the tongue speedily hatch the eggs, and the parasitic larvæ, by adhering to the organ, are conveyed into the mouth of the victim, whence they easily make their way into the stomach. Here they adhere to the mucous membrane by means of the mouth-hooks, and their presence in any number is by no means advantageous to their host. The best-known species is the *Gastrophilus equi*. Another (*G. hermorhoidalis*) goes directly to the lips of the Horses for the purpose of depositing its eggs. *G. elephantis* inhabits the stomach of the Elephant.



GASTRUS EQUI.

TRIBE V.—PUPIPARA.

This last tribe of the Diptera consists of a comparatively small number of exceedingly curious creatures which are persistently parasitic in their perfect state, which, however, in this case means throughout the whole of their active lives, seeing that the eggs are hatched and the larvæ retained and nourished within the body of the mother until they have arrived at maturity, when they are extruded and immediately pass to the pupa state. Only a single larva is developed at a time. From the structure of the ovaries they cannot be very prolific.



HIPPOBOSCA EQUINA.

FAMILY XXI.—HIPPOBOSCIDÆ.

In this family wings and halteres are generally present, though the insects do not seem to have much occasion for such organs, as they live parasitically upon the bodies of birds and mammals. They have a hard, depressed body; the head is placed horizontally, and bears large eyes; the antennæ are very short; the proboscis consists of the maxillæ and labrum alone, the labium being abbreviated; and the legs are articulated at the sides of a very broad pectoral plate, so that in some cases they seem to spring from the sides of the body. The wings are usually distinctly veined only towards the fore margin; they are sometimes deciduous, and sometimes altogether wanting; the halteres are small, free, and placed low down; and the tarsi have very strong bifid claws.



MELOPHAGUS OVINUS.



LIPOPTENA CERVI.

Hippobosca equina, the type of this family, is parasitic upon Horses; it is well known in the New Forest under the name of the Forest Fly. The Sheep Tick (*Melophagus ovinus*) is another well-known species; it has no wings, and the abdomen is widened posteriorly. The genus *Lipoptena* is peculiar in that the wings are deciduous; and singularly enough, in some cases at any rate, the winged individuals are found on

birds, while those which have lost their wings occur on quadrupeds. Thus *Lipoptena cervi* occurs wingless upon the Stag, and with wings upon Grouse; in the latter condition it has been described as distinct under the name of *Ornithobia pallida*. Many other species live upon birds; sometimes, as in the case of *Ornithomyia avicularia*, infesting many kinds of birds; sometimes confining themselves to particular species or genera, such as *Stenopteryx hirundinis*, which is particularly abundant upon young Swallows.

FAMILY XXII.—NYCTERIBIIDÆ.

The Nycteribiidæ are exclusively parasitic on Bats, and hence are commonly known as "Bat Lice." They are wingless, but have a pair of halteres placed upon the dorsal surface between the articulations of the posterior limbs. The head is very movable, and is usually carried thrown back into a cavity of the upper surface of the thorax; the eyes are small or deficient; the antennæ attached beneath the margin of the head; the proboscis filiform, with very large palpi; the long legs are articulated quite on the sides of the thorax; and the basal joint of the tarsi is very long.

These are curious, ungainly little creatures, more like flattened Spiders than anything; they rarely exceed a sixth of an inch in length, and are parasitic upon various species of Bats, dwelling especially in the cavity of the axilla. They are generally of a pale ochreous or leather colour, with the claws black. The British species live on the common Bats, such as *Vespertilio murinus* and *V. serotinus*, and are sometimes rather abundant. In collections they are rare.

FAMILY XXIII.—BRAULIDÆ.

This third and last family of the pupiparous Diptera includes only a single minute species, which is parasitic upon the Honey Bee, and seems to show a preference for the Drones. It has a large head, with neither eyes nor ocelli; short, two-jointed antennæ, immersed in deep cavities of the forehead; a small, ring-like thorax with a large stigma on each side, and a nearly circular abdomen. The legs are attached to the under surface of the body near the middle line, and the tarsi consist of four short joints and a much longer one at the extremity, the last bearing a pair of singular claws in the form of combs with long teeth. This Bee Louse (*Braula cæca*) is a minute creature about one-eighteenth of an inch long, of a rusty-brown colour. It lives upon the thorax of the Bees, its remarkably pectinated claws being particularly well adapted for clinging to the hairs with which that part is clothed.

ORDER APHANIPTERA.

This small order includes a few insects which are tolerably familiar to most people, namely, those exceedingly active and very troublesome little creatures, the Fleas. As already stated, they have been of late very commonly classed with the Diptera, but they differ so importantly from all true members of that order that we have thought it better to keep them separate. How far this course is justified will be seen when we have described the general characters of the insects forming the group.

In general form the body, as is probably pretty well known, is considerably compressed, and the insect has no wings. The three segments of the thorax, instead of being soldered together to form a single mass, are separate and similarly constructed, forming three narrow bands behind the head, the only difference between them being that the second and third segments bear on each side a peculiar plate or scale-like piece projecting from their hinder margins. The scales of the mesothorax are small, those of the metathorax much larger, and these parts have generally been regarded as representing the two pairs of wings. Attached to these thoracic segments are three pairs of legs, which are long and powerful. Their coxæ especially are very greatly developed; those of the front pair of legs project forward at the sides of the head, so as to protect the organs of the mouth, and those of the hinder pair are the largest. The trochanters are small; the femora broad and compressed, especially those of the hind legs, which exceed the others in size, and are adapted for leaping; and the tarsi consist of five joints. The eyes are small and round, and the antennæ are minute organs, composed of four joints, and enclosed in little cavities immediately behind the eyes. In the structure of the mouth (see Fig. c., p. 100) the Fleas both resemble and differ from the Diptera. The labrum is rudimentary, but the labium forms a rather delicate membranous organ, which is cleft throughout a good

part of its length, and has the two apical parts more or less distinctly jointed; the maxillæ are short, nearly triangular pieces at the sides of the mouth, but each of them bears a well-developed four-jointed palpus; the mandibles are long and thin, with serrated edges, and slightly hollowed lengthwise, so that when brought together they form a sheath for an unpaired organ (regarded as the same as the epipharynx of the Diptera), which somewhat resembles a three-cornered sword-blade, and is used for the same purpose, namely, that of piercing the flesh and shedding the blood of the bearer's victims. This three-cornered weapon is very deeply channelled below. It is, as already stated, enclosed between the mandibles; the long, cleft, membranous labium embraces these, and the whole constitutes an admirable apparatus for sucking up the blood set free by the puncture of the central piercing organ. The abdomen, which consists of eight segments, is covered, like the rest of the body, with a horny integument, and the hinder edges of all the segments, as also of the scales supposed to represent the wings, are garnished with rows of bristle-like hairs. The legs also are bristly.

It will be seen that in the principle of action of the mouth the Fleas undoubtedly resemble the Diptera, but on the other hand the two divisions of the labium are generally distinctly jointed, and evidently represent labial palpi, and thus, as Dr. Gerstäcker says, these insects form a distinct transition towards the next order (Rhynchota), as also by the segmentation of the body, and especially of the thorax, towards the Orthoptera, "so that they may be characterised as aberrant Diptera, with partial Orthopterous and Hemipterous characters." Insects so characterised are surely best placed in a niche by themselves.

In their transformations, however, the Fleas present another resemblance to the Diptera, and especially to the earlier families



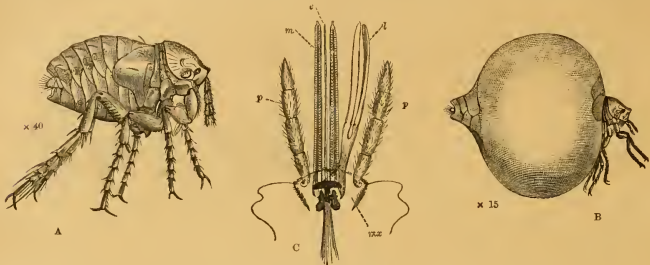
METAMORPHOSES OF THE COMMON FLEA.

of the order. The eggs, which are usually not numerous, are deposited by the female in suitable places for the development of the larvæ, such as obscure, dusty corners, among the hairs or feathers of the animals infested, or upon the articles on which these animals customarily lie. Thus these "nits" may always be found in the beds of House Dogs and Cats. From the eggs the larvæ are speedily hatched. They are long, worm-like, footless grubs, showing thirteen distinct segments, garnished with fine bristle-like hairs. The head is slightly horny, furnished with a pair of short antennæ and a mouth with biting organs, and the last segment is provided with a pair of horny hooks. These larvæ are active, twisting about in every direction, and feeding upon the nutritious parts of feathers and other refuse animal matter among which they live. In warm weather the larvæ are soon mature (twelve days is the average time in the case of the common Flea), and they then usually enclose themselves in a small silken cocoon, and there undergo the change to the pupa state. The pupa is quiescent, with the different parts enclosed in special cases, and the period during which the insects remain in this condition is usually about equal to that of their larval existence, except in the case of those inhabiting cold and temperate climates, many of which pass the winter in the pupa state.

The perfect insects, as is well known, feed upon the blood of warm-blooded animals, and, as a rule, each species of Flea is allotted to some particular species or group of species of mammals or birds. The insects conceal themselves among the hairs or feathers of the animal on whose blood they are destined to feed, and generally stick to this comfortable and convenient dwelling-place for the remainder of their joint lives, but it is curious to see how soon after the host is killed the parasites escape from its body and show manifest signs of perturbation. The common Flea (*Pulex irritans*) is the best known species, from its habit of drawing its supplies of food from our own persons. The Fleas of the Dog and Cat are distinct (*P. canis* and *P. felis*), and are chiefly confined to those animals, although they do not disdain to vary their diet occasionally with human blood.

Other species are still more particularly limited to certain animals, such as the Squirrel, the Hedgehog, the Mole, Mice and Rats, and Bats. The common Fowl also has its particular Flea (*P. gallinae*); another infests Pigeons, whilst others are found in the nests of small birds and Swallows. The largest British species lives on the Badger (*P. melis*), and measures an eighth of an inch long; an American species (*P. gigas*) is two lines in length, and a still larger species is described as infesting the Australian Porcupine Ant-eater (*Echidna hystrix*). The common Flea varies a good deal in size in different localities. Very large specimens are said to occur about the bathing accommodations of some watering-places, and the Flea of the old reading-room of the British Museum used to be noted for its magnitude and bloodthirstiness.

The muscular strength of the Fleas is exceedingly great. They perform the most astonishing leaps, covering at a single bound a space many times the length of their own bodies, a faculty which enables them to vanish in the most wonderful manner at the approach of the finger of an intending captor. This extraordinary muscular energy has been taken advantage of in a very curious manner,



SARCOPSYLLA PENETRANS.

A, Free Female; B, Female distended with Eggs; C, Organs of Mouth: m, Maxillæ; p, Palpi; l, Labium; m, Mandibles; e, Epipharynx.

Fleas having been trained to drag small coaches and other objects to which they were harnessed, and to perform other tricks, when they were exhibited to an admiring public under the title of "Industrious Fleas."

Besides the ordinary Fleas which occur in all parts of the world upon man and different animals, and which agree closely in their habits and mode of life, we have to notice an American species known as the Nigua, Chigoe, or Jigger (*Sarcopsylla penetrans*), the female of which has certain habits that render her a more unwelcome guest than the fiercest examples of *Pulex irritans*. It is a minute species, less than a twentieth of an inch in length, and lives chiefly in the open country, especially among sand—whence it is sometimes called the "Sand Flea"—but always in or in the vicinity of human habitations, either occupied or deserted. It ranges in America from Paraguay in the South up to Virginia in the North, that is to say, for nearly 30 degrees on each side of the equator, but is particularly abundant in the warmer parts of South America and the West Indies.

In its general habits and transformations, the Chigoe agrees with the rest of the Fleas, and the adult insects feed freely upon the blood of such men and animals as come in their way, until the time comes for the female to produce her eggs, when an entire change takes place in her habits, and she becomes a true parasite. The impregnated female, in fact, makes her way into the skin of the feet of men and animals, generally selecting the toes immediately beneath the nails or claws, but sometimes in the case of small mammals, such as Field Mice, going higher up the limb. In any case, she penetrates the skin until only the extremity of her abdomen is left in contact with the outer air, and it is through very curious stigmata in this part of the body that she now respire. The ovaries produce a great number of eggs, and these gradually swell up the abdomen till it frequently attains the size

of a pea, when nearly all signs of the original segmentation vanish, and the creature appears like a whitish globular bag, with the head and limbs appended to it in front. The skin of the abdomen is thickened, the internal organs become aborted, even the tracheæ disappear, and it would seem that the further development of the ova is effected, after a vegetative fashion, by the mere absorption and assimilation of fluids. When mature, the ova are expelled from the free orifice at the apex of the abdomen.

The older writers gave terrible accounts of the pernicious effects produced by this little insect, but later authorities, and especially Professor Karsten, speaking from observation and personal experience, do not represent it as quite so formidable. It would seem that a slight tickling and itching are the only symptoms produced by the ingress of the parasite, and that if the part in which it resides is not rubbed or irritated, its whole development may take place with no greater inconvenience. Pressure, friction, or irritation of any kind will, however, easily set up an inflammation of the part, and this, if neglected, may assume formidable proportions. Unskilful extraction may also cause disagreeable symptoms, but these are due to mechanical irritation, and not to the deposition of the eggs in the wound produced, as the larvæ are not parasites. The extraction of the insect is generally left until it has attained its full size, when the skin of the toe is carefully pushed aside from the globular abdomen with a knife or needle, and the whole body may then be gently removed. The development of the female usually takes less than a week after penetration into the skin of her victim.

CHAPTER XIII.

THE RHYNCHOTA, OR BEAKED INSECTS.

THE RHYNCHOTA—The Rostrum—General Form—Internal Anatomy—Imperfect Metamorphosis—Distribution—Fossil Species—Classification—HETEROPTERA, OR BUGS—Characters—LAND BUGS—SCUTATA, OR SHIELD BUGS—COREIDE—LYGEIDE—PYRRHOCORIDE—PHYTOCORIDE, OR PLANT BUGS—ANTHOCORIDE—MEMBRANACEA—The Bed Bug—REDUVIIDE—GERRIDE—HYDROCORES, OR WATER BUGS—GALGULIDE—NEPIDÆ, OR WATER SCORPIONS—NOTONECTIDE—HOMOPTERA—CICADIDE—Characters—Distribution—The Organs of Stridulation—FULGORIDE—The Great Lantern Fly—MEMBRACIDE—CICADELLINA—Cuckoo Spits—Froghoppers—PSYLLIDE—APHIDIDE—Plant Lice—Hop Fly—Reproduction—COCCIDE—Cochineal—PEDICULINA.

ORDER RHYNCHOTA.

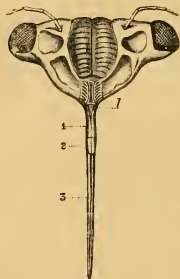
OUR readers will be inclined to think that they are being introduced to very unsatisfactory company. The last chapter treated of Fleas, and in the present one we have to deal with Bugs, and with some other insects, of which we shall at present only say that, according to Sir Hugh Evans, they are familiar beasts to man, and signify love. It is to be observed, however, that these highly objectionable creatures form but a small part of the order Rhynchota; that many of them, though often unsavoury, are of great beauty; and that the natural history of others is exceedingly interesting.

The Rhynchota constitute the first order of insects with an imperfect metamorphosis, and they have the mouth converted into a suctorial apparatus. They were placed by Linnæus in the same order as the Grasshoppers, Cockroaches, and allied forms which compose the typical section of the next order (Orthoptera), and the name of Hemiptera, which he gave to this composite group, bears reference to the peculiar construction of the fore wings in the Bugs. This name is still often applied by entomologists to the present order, but as it applies only to one division of the order, and its original use was very much wider, we have preferred following the example of the majority of Continental writers and adopting the name Rhynchota ("beaked insects"), which expresses the leading character by which the order is distinguished.

As in the case of the Diptera, the suctorial organ in the typical Rhynchota, which is commonly denominated the *rostrum*, includes in its composition all the principal parts of the mouth. The actual rostrum is a horny jointed organ, forming a longer or shorter tube, cleft above towards the base, and formed by the labium and its palpi, the latter making two half tubes, united in the middle line both above and below, and showing along one surface a suture of junction in continuation of

the basal cleft already mentioned. This cleft is closed by the more or less elongated labrum, which fits into it, and thus completes the tube. Within this tube we find four bristles representing the mandibles and maxillæ, which can be pushed forward and retracted by the action of muscles attached to their slightly enlarged bases, and thus serve, like the similar organs of the Diptera, to pierce the tissues of animals and plants, and enable the insects to suck up their juices. There are no maxillary palpi.

The general form of the body varies exceedingly, and so does the relation of the head to the thorax, but, as a rule, the three segments of the thorax are distinct and separate, and bear two pairs of wings, the texture of which differs much in the different subordinate groups. Usually the prothorax is greatly developed on the upper surface, and behind it we find a regular scutellum. In both these respects, as also in the frequent conversion of the fore wings into horny wing-cases, the Rhynchota resemble the Beetles. The tarsi never consist of more than three joints. The abdomen is formed of from six to nine segments, which, in those species which have horny fore wings, are horny only on the lower surface, and on this the stigmata are situated.



HEAD OF *CICADA PLEBEJA*.

1, Labrum; 2, 3, Joints of Rostrum.

Unlike the Diptera and Lepidoptera, the Rhynchota have no crop or sucking stomach appended to the œsophagus, which leads directly into a glandular stomach, followed by a long, convoluted intestine, often dilated in its course into a stomach-like sac. The last portion of the intestine is also frequently glandular, and receives the Malpighian vessels, of which four are generally present. The salivary glands are usually much developed and often of complicated structure, or furnished with complex salivary receptacles. Besides these glands, we find in the Bugs a glandular organ situated in the metathorax, which secretes a strongly and generally disagreeably scented fluid, discharged through a pair of special orifices close to the origin of the posterior pair of legs. The nervous system is very much condensed. Behind the head-ganglia the

ventral chain generally shows only two thoracic ganglia, of which the second is larger than its fellow, and evidently composed of two ganglia united into a single mass. The abdominal part of the chain is represented only by a pair of nerve-cords, from which nerves are given off to the various organs. In nearly all the Rhynchota we find a pair of compound eyes, generally of small or moderate size, and either two or three ocelli. The other sense-organs, the antennæ, vary greatly in structure, being sometimes quite short, composed of two or three joints and terminated by a bristle, sometimes long, and then consisting either of four or five joints of considerable length, or of a greater number up to about twenty.

The metamorphosis throughout the order is imperfect; indeed, in the *PEDICULINA*, there is no metamorphosis at all. The larvæ present a greater or less resemblance in general form to the perfect insect, and as they grow and change their skin the rudiments of the wings make their appearance and gradually increase in size, lying in cases placed on each side behind the prothorax. There is consequently no true pupa stage, the imago being gradually produced under the successive larva skins until the final moult; but the last stage before this takes place is usually denominated the pupa. The insect is active and has similar habits throughout its life, the only exception to this rule being presented by the males of the Cochineal insects, which become resting pupæ underneath the last larva skin, and are sometimes enclosed in a small cocoon.

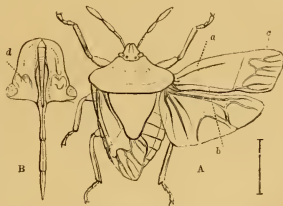
The food of most of the insects of this order consists of the juices of plants, which they suck up after piercing the tissues, as above mentioned, with the bristles which represent the mandibles and maxillæ. Some of these vegetable feeders have been observed occasionally to attack other insects and feed upon their juices, and the species of certain families are predaceous in their habits, and live entirely upon animal food. The *Pediculi* are parasitic upon Mammalia, whose blood they suck.

The species are found in all parts of the world, but the tropical regions are most favourable to their development, and it is here that we meet with the greatest number of species, and that they attain the largest size, the most curious forms, and the finest colours. Some of them are among the

most brilliant of insects. The number of known species is hard to estimate, but it is probably not less than 18,000.

From the descriptions of palæontologists it would appear that the Rhynchota are of great antiquity in the history of the world. Three species have been recorded from the Carboniferous formation, two of them being regarded as most nearly resembling the existing Fulgoridæ, or Lantern Flies. The Lias of Schambelen has furnished Prof. Heer with several fossil species belonging to this order, and representing both the principal groups into which the typical forms are divided; while the rich deposits of Solenhofen (Upper Oolite) contain a still larger number of species, some of them of considerable size. In England also the Lower Lias has furnished remains of Rhynchota, but none seem to have occurred in the Stonesfield Slate, or elsewhere in the English Oolites, until we come to the uppermost or Purbeck beds, in which such insects are tolerably numerous, and represent several existing families. It is as usual in the Tertiary beds that the traces of this order become most numerous, and in the deposits of (Eningen and Radoboj, so admirably worked out by Prof. Heer, the majority of the existing families are represented by more or less well-preserved examples.

The parasitic Pediculidæ (the Sucking Lice), which we place as degraded forms of this order, differ from the rest in so many important characters, but especially in the soft, fleshy, and retractile nature of their rostrum and the complete absence of wings, that we may fairly regard them as constituting a distinct sub-order, for which the name of *PEDICULINA* can be adopted. The remainder, or the typical Rhynchota, with very few exceptions, all possess the jointed rostrum above described as generally characteristic of the order, and in the exceptional cases this organ is altogether suppressed and not transformed into a fleshy sucker. These insects, however, may be divided into two groups, which are generally distinguished with facility by the structure of the fore wings. In one of them, including the numerous species of Bugs, the anterior wings almost invariably consist of two distinct parts, namely, a basal division, which is usually horny or leathery, and an apical part, which is more or less membranous. Hence the organs are commonly known as *Hemelytra*, and the sub-order is called *HETEROPTERA*. The membranous parts of the two wings, which are only occasionally absent, cross over one another at the apex of the body. The true wings are folded up beneath these hemelytra when closed. In the great majority of the species the rostrum originates at or towards the front of the head, and this character will serve to show the affinities of those species in which the wings are rudimentary or imperfectly developed. In the second sub-order the fore wings are of the same consistence throughout, or at any rate do not show that distinct division into two parts which is characteristic of the *Heteroptera* generally; hence they are called *Homoptera*. The fore wings may be horny or leathery; the hind wings are membranous, and generally smaller than the anterior pair. The latter generally do not cross each other at the apex when closed, but they are almost always placed upon the sides of the body in a sloping direction, meeting along the middle line in the form of a roof, whereas in the *Heteroptera* the closed wings generally lie flat upon the upper surface of the body. The two sub-orders further differ in the position of the rostrum, the face in the *Homoptera* being turned downwards, so that its true apex is brought into close contact with the sternum, and it is from this point that the jointed rostrum springs. Among the *Heteroptera* a somewhat similar arrangement occurs only in one family (*Notonectidæ*). The *Heteroptera* are regarded as the highest of the three groups, followed by the *Homoptera*, while the *Pediculina* constitute a somewhat aberrant series, although included by some entomologists under the *Homoptera*.



A, *PENTATOMA DISSIMILE*; B, UNDER SIDE OF HEAD AND ROSTRUM.

a, Corium; b, Clavus; c, Membrane; d, Tubercles for the Antennæ.

SUB-ORDER I.—HETEROPTERA, OR BUGS.

The characters distinguishing this group have already been sufficiently indicated for general purposes, but a few further details are necessary. The fore wings generally form protective coverings

for the more delicate hinder pair, and lie horizontally upon the upper surface of the body. From their function, and their being composed of two parts, they are, as has been said, generally denominated *hemelytra*; the horny basal part is called the *corium*, and the inner portion of this, bordering the scutellum, and marked off by a more or less distinct suture, is distinguished as the *clavus*. The thin apical part is the *membrane*, and generally shows some veins, the number and distribution of which are of importance in the discrimination of groups and species. The ocelli are generally present, and two in number. The antennæ, except in the aquatic families, are more or less elongated, and composed of four or five joints. They may be of about equal thickness throughout, or clubbed or reduced to a hair-like fineness at the extremity; in some instances some of the joints show signs of division, and the antennæ then look as if composed of more than five joints. These insects form two tribes, the members of which are respectively terrestrial and aquatic in their mode of life.

TRIBE GEOCORES, OR LAND BUGS.

The term "Running Bugs" would, perhaps, better express the habits of the insects of this tribe, as some of them frequent the water and even run briskly over its surface, while the members of the second tribe are essentially swimmers. The distinction of the two groups is, however, exceedingly easy, the Land Bugs having the antennæ freely exposed, and generally of moderate length, while in the Water Bugs those organs are of small size and concealed in cavities beneath the eyes.

FAMILY I.—SCUTATA, OR SHIELD BUGS.

The distinctive character referred to in the name of this family is the large size of the scutellum, the apex of which always reaches the base of the membrane (see Fig. A, p. 103), while in many cases the scutellum is so large as to cover nearly the whole upper surface, concealing the greater part of the hemelytra. The rostrum consists of four joints, and the labrum is long, reaching beyond the first joint of the rostrum, and transversely striated. The antennæ are usually of five joints, but sometimes only of three or four, attached to tubercles which are almost always concealed beneath the margins of the head (see Fig. B, p. 103), and there are two ocelli. The basal joint of the rostrum lies in a channel of the under side of the head.

These insects live upon plants, trees, and shrubs, and feed upon the juices which they suck out of the soft tissues, many of them especially attacking juicy fruits. Some species, however, have been detected in the act of varying this diet by imbibing the fluids of caterpillars. The family includes some of the largest of the Bugs, and is particularly well represented in the warmer parts of the globe, where also the most beautifully coloured species are met with. The *Callideæ*, for example, and the members of several genera nearly allied to them, inhabiting the tropical parts of the eastern hemisphere, are perfect gems when alive, showing the most splendid metallic tints, diversified with black spots. These belong to the section of the family in which the scutellum covers the whole back of the abdomen; one species (*Callidea stollii*) appearing dark blue with black spots, is very common in boxes of Chinese insects. But many other forms have during life a very fine metallic colouring which disappears after death. Traces of this may occasionally be seen in a very large species which is also a common inmate of the Chinese boxes (*Tessaratoma chinensis*), the specimens of which are usually over an inch long, and of a rather light brown colour with darker legs. The scutellum in this insect is triangular in form, as in the majority of the British and European species, which are not very numerous. One of the best known is the Red-legged Bug (*Tropicoris rufipes*), which measures about two-thirds of an inch in length, and has the sides of the prothorax produced into broad, pointed processes, and the tip of the scutellum occupied by a reddish spot, the rest of the surface being of a bronze-brown colour, with numerous large black punctures. A very pretty little native species, which lives on cruciferous plants, and is said sometimes to injure the cultivated varieties, may be called the Colewort Bug (*Strachia oleracea*). It is of a blue or greenish colour, variegated in the female with red and in the male with white markings. A nearly allied species (*S. ornata*), bright red with black markings, frequents the flowers of umbelliferous plants. Many exotic species of the same form show similar bright colours. The largest species belong to a special group, of which the Chinese *Tessaratoma* already referred to is an example. They have the rostrum much shorter than in the rest of the family, and the lateral angles of the prothorax

often produced into spines or horns. These are found in the warmer parts of both hemispheres, especially in South America and the East Indies. Those from the former belong chiefly to the great genus *Edessa*, and to some allied genera with five-jointed antennæ, while the majority of the Oriental species have those organs of four joints.

In temperate climates these insects generally keep themselves in concealment among herbage or the foliage of trees and bushes, but occasionally they fly freely in the sunshine. They winter in the winged state under the shelter of dried leaves or in moss, &c. The eggs are laid in the spring, and are of an oval or rounded form, furnished with a little lid which the larva pushes off in emerging.

FAMILY II.—COREIDÆ.

In this second family of the Geocores the scutellum is triangular, but does not reach the base of the membrane, the inner portions of the hemelytra (*clausus*) meeting beyond its apex in a straight suture. This character is common to most of the species of all the succeeding families. The antennæ are of four joints, and spring from tubercles placed on the sides of the head above an imaginary line drawn from the eyes to the base of the rostrum. The rostrum is four-jointed, with the basal joint usually the longest; the head bears two ocelli; and the hemelytral membrane has longitudinal veins, which are generally, as in the Scutata, rather numerous.

The number of European species is but small, and their size is generally insignificant, but in the tropics the species are very numerous, and generally of considerable size, some of them being the giants of the terrestrial Bugs. Many attain a length of an inch, while a few are an inch and a half or two inches long. Some of these large species, and a great many of the smaller ones, have the hinder thighs much thickened, especially in the males, while in some of these, and in others with slender thighs, the posterior tibiae are toothed, or dilated in a remarkable manner. This is particularly conspicuous in the South American genus *Anisocelis*, and the allied genus *Diactor*. A species of the latter is figured of the natural size in Plate 63, *z*. In a good many species the third joint of the antennæ is compressed or even more or less dilated, and in a few the second joint partakes of the same character. Some have the lateral angles of the prothorax produced into spines, or even into broad processes, which in a few are curved forward so as to give the prothorax a very marked crescent-like form. In a considerable number of species the body is comparatively narrow, the abdomen being scarcely wider than the closed hemelytra; in others the margins of the abdomen are wide, and project far beyond the sides of the hemelytra. This is the case in the most characteristic British species, *Syromastes marginatus* and *Verlusia rhombea*, the specific names of which relate to the prominence of the margins of the abdomen. Others, such as the species of *Berytus* and *Neides*, are exceedingly narrow and linear in their general form.

The insects of this family are rarely adorned with bright colours, different shades of brown being the prevailing tints, although some are more gaily adorned. In their general habits they much resemble the Shield Bugs, being found upon plants and trees, and flying readily during the heat of the day. The larger species produce a loud humming noise when on the wing. Their food appears to consist for the most part of vegetable juices, but some entomologists believe that they are more predaceous in their habits than the Shield Bugs.

FAMILY III.—LYGÆIDÆ.

The members of this family are, on the whole, much smaller than the Coreidæ, some of the smallest forms of which many of them much resemble. They also have a short, triangular scutellum, two ocelli, and four-jointed antennæ, but the latter organs spring from below a straight line drawn from the eyes to the base of the rostrum. The rostrum is of four nearly equal joints. The membrane of the hemelytra has usually four or five longitudinal veins.

The nearest approach to the preceding family is made by the typical genus *Lygæus*, which also includes the largest species. These insects are generally of a red colour with black bands and spots. None of these occur in Britain, but several species are found on the continent of Europe (*Lygæus equestris*, *L. saxatilis*, *L. familiaris*, &c.), all of which seem to have a wide distribution. The family is chiefly composed of a multitude of small species forming the genus *Rhyparochromus* and its allies, in which the body is usually black, and the corium of the hemelytra of some light brownish

or yellowish tint. The insects are found chiefly upon plants during the summer and autumn, and in moss or under dead leaves in winter. A few, such as *Platygaster ferrugineus*, which is very flat, winter under the bark of coniferous trees.

FAMILY IV.—PYRRHOCORIDÆ.

These insects, which may be denominated "Red Bugs," approach the typical *Lygæidæ* in some respects, especially in their being generally of a bright red colour with black spots and other markings, but they may be at once distinguished by the absence of ocelli, and the presence of numerous longitudinal veins in the membrane. They are found in most parts of the world, but, like

the other families, are more abundant and much larger in warm than in temperate climates. They are much more predaceous in their habits than any of the preceding.

One species of this especially tropical family occurs in the south of England, and is exceedingly abundant on the continent of Europe. It is known as *Pyrrhocoris apterus*, the specific name having reference to the absence of the wings and of the membrane of the hemelytra in most specimens found in cold or temperate regions. It is about



PYRRHOCORIS APTERUS.

a third of an inch long, and of a scarlet colour, with the head, the disc of the prothorax, the scutellum, the clavus, a spot upon each hemelytron, and the abdomen and limbs black. These insects usually occur in great numbers together, so as to produce the appearance of bright red patches about the foot of the trees, especially lime trees, which they frequent. They feed upon the juices of plants and fruits, but also to a great extent upon fluid sucked from the bodies of other insects, not even sparing young individuals of their own kind.

FAMILY V.—PHYTOCORIDÆ, OR PLANT BUGS.

These insects agree with those of the last family in wanting the ocelli; they also have a rostrum and antennæ composed of four joints; but they differ from all the preceding Bugs in the structure of the hemelytra. In these organs the outer apical angle of the corium is cut off from the rest by a transverse suture, so that it forms a separate triangular piece (*appendix*); and the only veins in the membrane itself form one or two cells at its base. The integuments of the body are rather soft, and the antennæ have the second joint long and the third and fourth usually very slender.

The Phytocoridæ abound in most parts of the world, and in Europe and Britain are undoubtedly the most numerously represented of all the families of Bugs. They may be found in the greatest abundance during the summer upon plants, bushes, and trees, and especially upon the low herbage of hedge bottoms. Several species may always be obtained during the summer from the nettles which usually

grow in the last-mentioned situation. They feed chiefly upon the juices of the plants on which they live, and on which they run with great rapidity when disturbed; they also fly freely in bright weather. A very common species on nettles is the *Phytocoris tripustulatus*, which is about a sixth of an inch in length and of an oval form. Its general colour is yellowish, with black markings on the hinder margin of the prothorax, the scutellum bright orange, and the hemelytra nearly black, with three orange yellow spots on the outer margin, the hindmost of which occupies the appendix. In the genus *Capsus* and its allies, the second joint of the antennæ is thickened, especially towards its apex. *Capsus capillaris*, which is also abundant upon nettles, varies in colour from red to black, but has always a red spot in the appendix. This species is rather more than a quarter of an inch long. A rather smaller species (*Capsus ater*) is common upon herbage; the male is entirely black, in the female the head and thorax are reddish. The genus *Miris* and its allies include elongated species, which are found chiefly in grassy places.

FAMILY VI.—ANTHOCORIDÆ.

Under this title we include a number of generally minute Bugs, which show curious affinities to the Lygeidae, to the Phytocoridae, and to certain species of the next family, especially the Bed Bug, which, indeed, has been included in the present group by some entomologists. They are small flat-bodied insects, having antennæ of four joints, with the last two generally more slender than the preceding ones, two ocelli, a rostrum apparently or really of three joints, and not enclosed in a furrow, and elytra, when fully developed, possessing an appendix like that of the Phytocoridae. The membrane has a basal cell, from which three or four short veins usually proceed. Few of the species exceed an eighth of an inch in length; the largest of our native forms (*Anthocoris nemorum* and *A. nemoralis*) do not attain more than the sixth of an inch. They are elliptical, black, with the hemelytra paler, but with dark or black markings; the front of the head, in most species of the group, is produced between the bases of the antennæ as a sort of snout. They are common on different kinds of trees and bushes during the summer months, and often frequent dead branches. Other species are found either all the year round or during the winter in the dead branches or under the bark of trees, whilst others are to be met with among vegetable rubbish of various kinds. Although so small and delicate in their structure, they appear to be predaceous in their habits, sucking out the juices of other insects and their larvæ.

FAMILY VII.—MEMBRANACEA.

In this family we have a slightly heterogeneous assemblage of forms, which, however, are certainly nearly allied to each other, and have generally been placed together by entomologists. They agree in the possession of four-jointed antennæ and of a three-jointed rostrum, which is enclosed in a sort of channel formed by a pair of keels running down the lower surface of the head and the sternum as far as the rostrum extends, in the flattened form of the body, and in having tarsi with only two joints. The ocelli are generally absent. In the majority the antennæ are thickened or clavate at the extremity, but in the Bed Bug and some allied species the third and fourth joints are more slender than the first and second.

The Bed Bug (*Acanthia lectularia*), which is only too well known to most people, besides the character of the antennæ just mentioned, is further distinguished by the rudimentary condition of the wings, the hind wings being altogether absent, and the hemelytra represented only by a pair of little convex organs, like small shells, situated just behind the prothorax. Although treated as a British insect, it does not appear to have been always an inhabitant of that country, but to have made its way there about the beginning of the sixteenth century. Even now there are many out-of-the-way places even in England where the insect is still unknown. The notion that it was introduced and spread by the importation of timber from America seems to be quite unfounded, as the Bed Bug was certainly known to the ancients, and is mentioned by both Greek and Roman authors. Three other British species have been described as inhabiting the dwelling-places of certain animals and feeding on their blood; *A. columbaria* attacking Pigeons, *A. hirundinis* found in Martins' nests, and *A. pipistrelli* feeding on Bats. The first of these is very near *A. lectularia* and may not be distinct. A few more species are known from different parts of the world,



BED BUG.

In the remainder of the family the hemelytra and wings are generally well developed, but the insects exhibit the same flattened form as the unwelcome inhabitant of our sleeping rooms, and like it are able to make their way into very confined spaces. Many of them reside habitually under the loose bark of dead trees, where they are generally found associated in some numbers. *Aradus depressus*, the most abundant native species of these Bark Bugs, is less than a quarter of an inch long, blackish-brown with lighter granules, with the greater part of the lateral margins of the prothorax yellowish-white, and the hemelytra of the same colour, but mottled and variegated with brown. It is found under loose bark and in moss. These insects are probably predaceous, but according to some writers they feed on fungi.

The species of the genus *Tingis* and its allies are minute and exceedingly delicate creatures, having the margins of the thorax and the whole of the hemelytra quite membranaceous and generally reticulated with numerous veins. One of the best known species (*Monanthia cardui*) is found abundantly upon thistles. It is about an eighth of an inch long, of a greyish colour, variegated with small black spots. Other species are still more elegant, having the membranous parts quite transparent, with black veins. They are found upon various trees and plants, chiefly herbaceous, upon the juices of which they appear to feed.

In the insects just mentioned the scutellum is usually concealed by a projection of the hinder margin of the thorax: in another group of the family it is exposed, and sometimes even attains a large size. These insects, which are generally inhabitants of warm countries, have the fore legs converted into raptorial organs, and possess two ocelli. Two species (*Syrts crassipes* and *S. monstrosa*) are found in Central and Southern Europe.

FAMILY VIII.—REDUVIIDÆ.

This is a great group of insects presenting much analogy with that which we have included under the family Coreidæ, both in general form and in the modifications which that form undergoes



REDUVIUS PERSONATUS.

in the various members, but differing from them nevertheless in several important characters. They have the head of various forms, but always constricted behind so as to form a regular neck, and in front of this there are two distinct ocelli. The antennæ are four-jointed, with the last two joints generally thinner than the first and second; the rostrum, which is not enclosed in a furrow, is composed of three joints, and is generally a short, stout, and powerful organ; the legs are generally long, with short, three-jointed tarsi, and the anterior pair are some-

times converted into raptorial limbs. All these insects, the species of which are exceedingly numerous in tropical regions, are predaceous in their habits, attacking and sucking out the juices

of other insects, a predatory course of life for which the powerful typical species are particularly well fitted. Many of them, when seized, will inflict a severe wound upon their captor.

The largest British species is *Reduvius personatus*, an insect about three-quarters of an inch long, of a blackish-brown colour, with reddish legs. It is well furnished with wings, and flies especially in warm summer evenings, when it frequently enters houses, being attracted by the lights. Its larva, which haunts concealed corners, disguises itself by means of a covering formed of its own excrements mixed with extraneous particles, and both larva and perfect insect, when in houses, are said to display a special enmity to the Bed Bug. Three or four species of the genus *Nabis* occur in Britain on herbage, generally under the shelter of bushes. They are nearly elliptical, but more narrowed in front, and generally of a brownish tint on the upper surface. The hemelytra and wings are often imperfectly developed in these insects. A near ally of theirs, a very scarce British species, is of a beautiful blue-black, with the hemelytra and legs bright scarlet, but the former are never fully developed in northern examples. Its name is *Metastemma gattula*, and it represents a group of Bugs, of which the typical genus is appropriately named *Pirates*, including some of the largest and most powerful insects of this family.

The very opposite peculiarities are presented by the *Hydrometra stagnorum*, which in many respects leads us towards the next family. It is a slender, elongated creature, about half an inch long, with the antennæ and legs also exceedingly long and thin, which is found on the margins of pieces of water crawling slowly about upon aquatic plants and the vegetable *débris* which generally occur in such situations. The articulations of the legs are situated at the sides of the thoracic segments, as in the Bugs of the following family, and the insect occasionally walks upon the surface of the water just as they do.

FAMILY IX.—GERRIDÆ.

This last family of the Geocores includes some exceedingly well-known insects, which may be seen running actively over the surface of every piece of water. They have a broad head, which is not contracted behind into a neck, four-jointed antennæ and a three-jointed rostrum, of which the second joint is the longest. The legs are inserted quite at the sides of the thorax, and the tarsi are of two joints, with the claws inserted, not at the apex of the last joint, but in a notch of its under side. These insects, of which several species are abundant in Britain, have boat-shaped bodies, and the typical forms, such as *Gerris lacustris*, which may be met with anywhere, literally row themselves along the surface of the water by means of their long legs, their power of floating being aided by the coating of silvery hair which covers their lower surface and carries with it a portion of air. They are predaceous in their habits, feeding upon other insects. Some nearly allied, but mostly very small species, with legs even longer in proportion than those of our common forms, are met with at sea within the tropics, and often at a great distance from land. They form two or three genera, of which the best known is *Halobates*.

TRIBE II.—HYDROCORES, OR WATER BUGS.

As already stated, these insects are distinguished by the possession of very short antennæ concealed in pits near the eyes. The tribe includes three families, two of which are well represented in Europe and Britain, while the third is exclusively American. The last-mentioned family is the most nearly related to the preceding forms.

FAMILY X.—GALGULIDÆ.

This family is at once distinguished from the rest of the tribe by the presence of a pair of ocelli on the crown of the head. The body is flat, and the head broad and immersed up to the eyes in the thorax; the eyes are prominent; the antennæ composed of four joints; the rostrum three-jointed, and the membrane of the hemelytra small. The legs are formed for running, and the species live on the banks of rivers and lakes, where they prey upon other insects. The best-known species (*Galgulus oculatus*), an insect about two-fifths of an inch long, of a blackish-brown colour, inhabits the southern parts of the United States. The fore legs have the femora thickened, and are somewhat raptorial in character, and this peculiarity is much more strongly marked in the species of *Mononyx*, which are found in South America, and in which the fore tarsi are represented only by a sort of claw.

FAMILY XI.—NEPIDÆ, OR WATER SCORPIONS.

In this family the ocelli are wanting, the antennæ are either three- or four-jointed, the body is flat above, elliptical or much elongated, and the hemelytra are furnished with a distinct membrane. The rostrum is of three joints. The fore legs in all are raptorial; the remainder are either simple, fringed, or flattened, but in all cases are used as swimming organs. All the species live in the water and prey upon their weaker fellows. They are, however, well furnished with wings, and can fly readily, a provision which is useful in case of any need arising for seeking a new abode.

The common Water Scorpion (*Nepa cinerea*) is a very well-known aquatic insect, and is abundant in the fresh waters of all parts of Europe. It is about an inch long, elliptical, yellowish-grey, with the



RANATRA LINEARIS AND NEPA CINEREA.

very elongated body, whence the British species is called *Ranatra linearis*. Its legs much lengthened, and the four hinder tibiae rather more fringed than in *Nepa*.

Another division of the family having four-jointed antennæ, two-jointed hinder tarsi, and no breathing tube, is represented in Britain by a small oval species, about half an inch long, of an olive brown tint, known as *Naucoris cimicoides*. It has a broad, deeply-immersed head; the anterior tarsi consist of a single joint; and the hinder tibiae and tarsi are fringed, so that the insect is a more active swimmer than the Water Scorpion. When handled it is able to inflict a painful wound. Some of the exotic allies of this species are among the giants of the order, or indeed of the insect world. Thus the *Belostoma grande*, a native of South America, measures over four inches in length. This must be a most formidable enemy to the weaker inhabitants of the fresh waters of Brazil and Guiana, as besides its large size, it is favoured by having the hinder legs widened into regular paddles, which must enable it to swim with great rapidity. Other allied species of nearly equal size occur in the tropical parts of both hemispheres. The females of some of the smaller tropical forms (*Diplonychus*, &c.) deposit their eggs close together upon their backs, and thus carry them about.

FAMILY XII.—NOTONECTIDÆ.

The Notonectidæ have a broad head with the forehead rounded and turned down, so that the insertion of the rostrum is brought close to the anterior margin of the sternum. The body is convex

back of the abdomen red; the antennæ have three joints; the hinder legs are scarcely fringed, and have tarsi of a single joint; and the body is terminated by a pair of tail-like organs, which, when put together, form a breathing tube. The insect is sluggish in its movements. The female attaches her eggs to water plants. They have at the upper end seven radiating processes. The *Ranatra*, which resemble the preceding in the characters of the antennæ, tarsi, and air-tube, have a They have the fore

above and flat below; the antennæ are four-jointed; the ocelli are wanting; and the hinder tibia and tarsi are much compressed and strongly fringed on both sides, rendering the insects very active swimmers. The familiar name of "Water Boatmen" is often applied to the typical forms of this family, in allusion to the appearance they present when resting and taking in air at the surface of the water; the long hinder legs are then thrown out nearly at right angles to the body after the fashion of a waterman resting on his sculls (see centre figure on p. 110).

The British *Notonecta glauca* is an insect rather more than half an inch long, of a yellowish colour above, with the scutellum black. As implied in its name, it swims with its lower surface upwards, and is exceedingly expert in that exercise, while it also flies very well by means of a pair of most beautiful filmy wings which are folded up beneath the roof-like hemelytra. It is a most predaceous insect, and can bite severely.

Still commoner than the above are the species of the genus *Corixa*, the largest British representative of which (*Corixa geoffroyi*) is nearly half an inch long. These insects, which are flatter on the upper surface than the true *Notonecta*, are to be met with in nearly every piece of stagnant water. They swim with their backs upwards, and are not so powerful and active as *N. glauca*.



NOTONECTA GLAUCA.

SUBORDER II.—HOMOPTERA.

As already pointed out, the most striking general character of this group consists in the uniform texture of the fore wings, which never show the clear division into corium and membrane exhibited by the great majority of the Bugs. The wings also do not, except in a few instances, cross each other at the tip, and in by far the greater number they are placed slantingly on the sides of the body, so as to make a roof-like covering. Where the wing characters are obscure the position of the origin of the rostrum will at once determine to which division an insect belongs. In all the Homoptera this organ springs from the hinder part of the lower surface of the head close to the sternum (see figure on p. 102), or even in some cases apparently from the sternum itself. These insects all feed upon vegetable juices.

FAMILY XIII.—CICADIDÆ.

The insects forming this family, which have always been placed at the head of the Homoptera, are of moderate or large size and robust conformation, and may be at once distinguished from all the rest by the possession of three very distinct ocelli upon the crown of the head. The head itself is generally broad, short, and vertical, and terminated below by a rather long rostrum composed of three joints. The forehead is considerably inflated, and marked with fine transverse furrows; the eyes are prominent; the short antennæ originate close to the eyes, and are of seven joints, which gradually diminish in thickness so that the organ is like a bristle; the scutellum is large, inflated, and notched behind; and the fore wings are much larger than the posterior pair, and generally show only a moderate number of very definitely arranged veins.

Of the four or five hundred known species of this family, by far the greater number inhabit tropical countries, and it is in such regions that the species attain the greatest size. Thus, *Tacca speriosa* (Plate 63, A), a magnificent black species, with a broad yellow band across the hinder margin, and part of the anterior margin of the same colour, is a native of Java and the neighbouring islands. The females often measure over three inches in length when the wings are closed, and species of equal, or nearly equal, dimensions are met with throughout the tropical parts of the world. A large black species with transparent wings (*Fidicina atrata*) is common in Chinese boxes, which also contain a rather smaller form, black with yellow spots (*Gæana maculata*), and a still smaller black species with the forehead, two large spots on the mesothorax, and the abdomen blood red (*Huechys sanguinea*). On the continent of Europe about eighteen species are recognised, and one of the smallest of these (*Cicada hematodes*) occurs in the south of England, in the New Forest, where, however it seems to be rare.



LARVA AND PUPA OF CICADA.

These insects live upon trees and shrubs, and obtain their nourishment by piercing the tissues and sucking out the juices of their young tender shoots. In some cases the flow of juice continues after the withdrawal of the pumping apparatus of the Cicada, and the fluid hardening on the surface of the twigs becomes the substance known as *Manna*.* This applies especially to a species that infests ash-trees in most parts of Europe and over a considerable portion of Asia (*Cicada orni*), which is, in fact, the common Cicada of Southern Europe.

The female Cicada is furnished with a powerful serrated ovipositor, by means of which she cuts deeply into the dead branches of the trees on which she lives, and deposits her eggs in the grooves thus formed. The larvae, when hatched, are little, plump, stout-limbed insects, and they speedily make their way beneath the surface of the ground, where they live by sucking the juices from the roots of trees and plants. They appear generally to pass at least two years in their preparatory states, and some are said to be much longer in arriving at maturity. One North American species is called the *Seventeen-years' Locust* (*Cicada septendecim*), because it is said to appear only at intervals of seventeen years in any given locality.

The male Cicadae are endowed with a noise-producing power which renders them most troublesome in places where they abound. During the heat of the day they sit concealed among the foliage of the trees and shrubs, and sing incessantly. This habit has been referred to by the



UNDER SURFACE OF
MALE 'CICADA.

classic poets in many passages, which indicate that for some reasons the song of the Cicada was regarded by them as by no means unpleasant, and, in fact, even at the present day, in countries where the insects abound, it is a common practice to keep them in cages, probably for the purpose of reminding town-dwellers of the delights of the country. The organs by which this often violent stridulation is produced are situated at the base of the abdomen, in two cavities enclosed by large horny plates, which are represented upon a smaller scale in the females also. The special organs enclosed in these cavities consist of elastic folded membranes attached to a horny ring, and the noise has generally been described as produced by vibrations of these membranes, caused by the action of muscles originating from the median partition of the second abdominal segment. According to Dr. Landois, however, the "drum," as the above-mentioned special membrane has been called, cannot act in the manner described, but is firmly attached to the wall of the metathorax. He considers the true organs of sound to be the stigmae of the metathorax, which are very large and elongated, and furnished throughout their length with a pair of thin sound-bands, leaving a very narrow slit between them. The vibration of these bands during the expulsion of air from the

trachea produces the sound, which the external organs only increase in power. The females have no voice, as was well known to the ancients—in fact, one Greek poet most ungallantly congratulates the male Cicadae on the silence of their partners.

FAMILY XIV.—FULGORIDÆ.

In these insects, as in the two succeeding families, there are never more than two ocelli, but these are rarely wanting, and are placed near the compound eyes. The head is exceedingly variable in its form, but the forehead is always separated both from the crown of the head and from the cheeks by well-marked ridges or keels. The antennae, which consist of three joints, and are usually short and terminated by a bristle, spring from the cheeks beneath the eyes; the prothorax is a simple ordinary segment; the middle coxae are elongated and widely spread, and the tibiae are generally three-cornered and often spinous. The hind limbs are usually leaping organs, and their tibiae have a circlet of spines at the apex, often accompanied by one or two of larger size. There is no trace of singing organs such as are possessed by the Cicadae. In many of the Fulgoridæ the front of the head is produced into processes, sometimes of the most fantastic form; and most of them produce from the skin a sort of waxy secretion, which usually forms white powdery-looking patches on the abdomen, but is frequently much more abundant, and constitutes stout white threads, which may entirely cover and conceal the abdomen, and extend for some distance beyond its apex. This

* Most of the manna of commerce, however, is obtained artificially by incisions made in the bark of the ash-trees.



EXOTIC RHYNCHOTA

A, *Taenia speciosa*; B, *Fulgora etelaria*; C, *Cercopis bivittata*; D, *Tettigonia quadripunctata*; E, *Heteronotus reticulatus*; F, *Membracis elevata*; G, *Membracis cruenta*; H, *Hypsauchenia balista*; I, *Hemiptycha punctata*; J, *Diactor bilineatus*.

secretion is produced by the larvæ as well as the perfect insects. That of a Chinese species (*Flata limbata*) is collected for sale, and known in commerce as "Chinese white wax."

The processes of the head in the typical Fulgoride are often of considerable size, and, according to the older writers, had the power of diffusing a considerable amount of light from their extremity, whence the insects are commonly known as "Lantern Flies." The Great Lantern Fly (*Fulgora laternaria*), a native of Surinam, Brazil, and other parts of the South American Continent, attains a length of nearly three inches, and its wings spread nearly twice that distance. Its head-process, or lantern, is about an inch long, stout, and much inflated, with two large humps on the upper surface. The general colour is yellowish-brown, but each hind wing has a large, orange-yellow, ocellated spot, bordered with dark brown, and enclosing two bluish pupils. It is this insect, especially, that has been described as luminous; but the researches of modern travellers, if they



GREAT LANTERN FLY.

have not altogether disproved its possession of this property, have, at least, rendered it exceedingly doubtful. The Chinese Lantern Fly (*Fulgora candelaria*), a very common insect in all Chinese boxes, is shown in our Plate 63, B. It has a red body, greenish fore wings with yellow spots, and orange hind wings with black tips. Many other forms of these flies, with or without head-processes, are found throughout the tropics.

The European and British species are all of small size, and generally of dull colours. They are found upon trees, shrubs, and herbage. *Cixius nervosus*, an insect rather more than a quarter of an inch long, is black, with yellow legs, and transparent fore wings, in which the veins are dotted with brown, and there are two transverse brown bands. It is found chiefly on alders. The species of the allied genus *Delphacæ* occur principally on herbage; in *Asiraca* (*A. clavicornis*) the antennæ are elongated, nearly half as long as the body; and in *Issus* (*I. coleoptratus*), the ocelli are indistinct, and the fore wings are leathery and humped, like a pair of convex elytra.

FAMILY XV.—MEMBRACIDÆ.

If in the Fulgoride the head occasionally, as we have seen, takes on a fantastic shape, in the Membracide the prothorax fairly astonishes us by the extraordinary forms which it assumes. It is enlarged and produced into processes of the most varied kinds, and very frequently has a posterior part which wholly or partially covers the abdomen and wings. The head is bent down, furnished with two ocelli, and with a pair of very short antennæ, but the crown of the head is not separated in any way from the forehead. The wings are generally membranous. The species of this very remarkable family, which includes some of the most *bizarre* of insects, are chiefly inhabitants of

America, where they occur in wonderful abundance and variety. Our figures (E, F, G, H, I, in Plate 63) will show some of the curious forms that they assume. Some of the most remarkable are the species



BOCYDIUM TINTINNABULIFERUM.

of *Bocydius*—black insects, with transparent wings, the prothorax of which bears a perpendicular process, terminating in a knob, from the sides of which issue two branches, also branched and knobbed, whilst from behind is given off a long slender process, extending about as far as the extremity of the closed wings. Several species occur in South America, and from the slenderness of these singular thoracic processes, some of them are very elegant little creatures.

The extra-American species of this group belong chiefly to the genus *Centrotus*, one species of which (*C. cornutus*) is common in Britain and Europe. It is rather over a quarter of an inch long, black, with a pair of upright horns on the prothorax, which is also produced behind into a long, pointed, keeled spine. Another common European and British species (*Gurgara gemistæ*) is smaller than the preceding, and has no horns on the prothorax.

FAMILY XVI.—CICADELLINA.

We apply this term to a very extensive group of Homoptera, of small or moderate size, which in many respects may be regarded as the analogues of the Phytocoridae among the Bugs. In these insects we find the prothorax of ordinary form and proportions, without any of those enlargements or processes which characterise the preceding family, and the head, instead of being pressed downwards, projects freely in front of the thorax, with the crown directed upwards and the forehead forwards, the two surfaces usually meeting under a distinct angle. There are usually two ocelli; the antennæ are short, and composed of two joints with a terminal bristle; the upper wings are leathery; and the hind legs elongated and converted into leaping organs. These insects are distributed over all parts of the world, and, with the exception of the Aphides, they constitute the most numerous represented group of Homoptera in Europe and Britain. They live in all stages upon trees, shrubs, and plants, on the juices of which they feed, and the larvæ and pupæ very commonly surround themselves with a dense frothy secretion, whence the common name of "Cuckoo-spits" has been applied to them.

Two groups of these insects may be distinguished, and these are usually easily recognised by the form of the hinder limbs. In the *CERCOPIDÆ* these organs are smooth, or furnished only with two or three spines arranged one behind the other on their hinder surface, and the posterior coxæ are short. This group includes the largest species, some of the exotic species attaining a length of about an inch. A Javanese species approaching this length (*Cercopis bivittata*) is shown on our Plate 63, c. It is shining black, with two white bands across the fore wings. Black and red are more common colours in the genus *Cercopis*, one species of which, so adorned (*C. sanguinolenta*), is common on the continent, and occurs in Britain. The most abundant European species of this group, however, are the *Aphrophoræ*, which are the best known of the Cuckoo-spits, or Froghoppers. *Aphrophora spumaria*, an insect nearly half an inch long, is common in Britain on trees and bushes, especially willows; a smaller species (*A. bifasciata*) is found abundantly upon rose-bushes and other plants in every garden.

The *JASSIDÆ* have the hinder coxæ transverse, and the hind tibiæ furnished with two rows of more or less distinct spines along their posterior surface. They are exceedingly numerous, and often remarkably elegant in form. The species of *Tettigonia* *T. quadripunctata*, Plate 63, d) especially are frequently of great beauty. They are mostly inhabitants of America, whence some three or four hundred species have been described, but we find in England an exceedingly pretty green species (*T. viridis*), which is common in damp meadows. The species of *Typhlocyba*, which are exceedingly abundant on plants everywhere, resemble the *Tettigonia* in general form, but are more slender, and generally very small and delicate creatures. They have no ocelli.

FAMILY XVII.—PSYLLIDÆ.

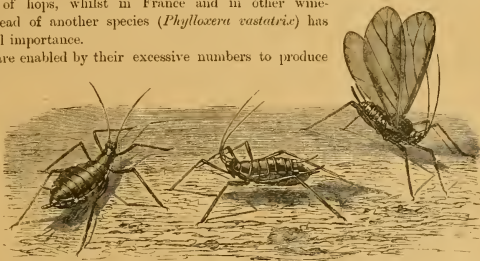
This is the first family of the so-called Plant Lice, and is distinguished by having long, freely-projecting antennæ of eight or ten joints, with a pair of fine bristles at the extremity of the last joint,

three ocelli, and short legs with the femora thickened, adapting the insects for springing, which they do with as much activity as the Froghoppers. The tarsi are of two joints, and the fore wings are generally somewhat leathery. These are minute insects which live upon various plants and trees, each species, however, usually being restricted to some particular kind of plant. Their bodies, especially those of the larvæ, generally show a powdery white coating, analogous to that noticed as occurring in the Fulgoridæ. The species rarely exceed an eighth of an inch in length. By attacking the young shoots, and especially the inflorescence of trees, the larvæ often give rise to considerable deformation of the parts. Common species occur upon the alder, the ash, the pear-tree, the oak, and the nettle.

FAMILY XVIII.—APHIDIDÆ.

This exceedingly interesting family, which includes the insects commonly known as "Plant Lice," is so abundantly represented everywhere, that some of its forms must be familiar to all our readers. Every one must have noticed the green Aphides which swarm upon roses, and the black ones of the bean, whilst a host of other species, more or less resembling these, are to be found upon almost every plant in the garden or the field. Small and feeble as they are, they often force themselves upon the attention of the farmer and the gardener by the injury they do to cultivated plants. In England the abundance or scarcity of the Hop Fly (*Aphis*, or *Phorodon humuli*) is a most important matter to the cultivator of hops, whilst in France and in other wine-growing countries the spread of another species (*Phylloxera vastatrix*) has become a matter of national importance.

The creatures, which are enabled by their excessive numbers to produce such serious results, are individually of the very feeblest. They have a soft, tender body, generally of an ovate shape, and usually long, thin, and feeble legs; their tarsi are of two joints; their antennæ are more or less elongated, composed of from five to seven joints; the crown of the head has no ocelli;



ROSE APHIS.

and the rostrum is three-jointed, sometimes very long, but sometimes altogether wanting in certain developmental forms. The wings also are frequently deficient, sometimes in all the individuals of a species, sometimes again in particular developmental forms. When present they are membranous, with few veins, generally resting in a roof-like form over the abdomen, and the hind wings are much smaller than the anterior pair. In most of the species the abdomen bears a pair of tubes or perforated tubercles upon the last segment but two. From these, which are known as honey-tubes or *corniculi*, a sweet fluid is poured forth in small drops, and is a great attraction to Ants and many other Hymenopterous and Dipterous insects. When secreted in great abundance this fluid often drops from the branches of the trees infested by Aphides, and is then commonly known as "honey-dew."

These insects generally live on the leaves and tender shoots of trees, shrubs, and herbaceous plants, the tissues of which they pierce in order to suck out the juices. They are sluggish creatures, generally remaining fixed in the same spot, with the rostrum deeply inserted; but they can shift their position to short distances by slow and feeble walking, and make wider excursions by the aid of the wings with which some forms of each species are generally provided. In many cases the attacks of the Aphides are directed to the roots of plants, and some of these are taken possession of by Ants, who treat them as herds of miniature milch-cows (see Vol. V., p. 381), but it seems doubtful whether these forms, which are always apterous, are more than stages of the development of species, other forms of which live above ground. A few species belonging to the genus *Lachnus* and its allies, which have the rostrum very long, live in the fissures of the bark of trees. One example,

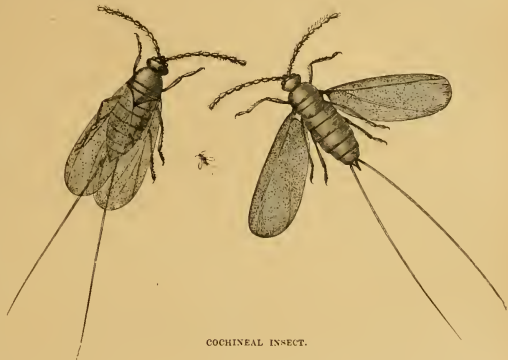
known commonly as the "American blight" (*Schizoneura lanigera*), a small insect covered with a white cotton-like secretion, often does much injury to apple-trees. Three species of *Lachnus* are found upon the oak. Of the species haunting the leafy parts of trees, a considerable number produce great deformations of the parts they attack, which grow out into gall-like or bladder-like structures, within which the Aphides reside. The leaves and leaf-stalks are the parts chiefly affected in this way, and the effect produced varies from a mere crinkling of the leaf to the formation of a regular sac having only a narrow slit of communication with the outer world. Such structures may be constantly found upon poplars and the various kinds of willows and willows.

The reproduction of the Aphides constitutes one of the most interesting chapters in the history of the Animal Kingdom. In the late autumn, males and true oviparous females make their appearance, and the latter, after fertilisation, deposit their eggs in sheltered situations, where they remain until the spring. Among the progeny of these eggs there are no males, and after changing their skins three or four times the insects arrive at their mature form, when they give origin, asexually, to another generation also of asexual forms, and this process goes on throughout the summer. These asexual forms are generally viviparous, the young being produced by a process of internal budding from organs representing the ovaries of the perfect females, and they usually show, at the time of their birth, the rudiments of the next generation. These asexual forms may be either winged or wingless, and their production under favourable conditions may go on for a long time. Thus Bonnet observed the production of nine, and Duvau of eleven generations, whilst Kyber, by keeping a colony of Aphides in a warm room, was enabled to continue their asexual reproduction for four years. This, therefore, is a very complex case of "alternation of generations," the whole of the individuals produced between one asexual generation and the next having to be regarded as larval forms, whether winged or apterous. It would appear, however, from recent investigations, and especially from those of M. Jules Lichtenstein, that matters are not quite so simple as above stated, at all events, in the case of some species observed by him, though how far his results will apply to the whole family is at present a matter for further investigation. In the case of the Phylloxera of the oak (*Phylloxera quercus*), M. Lichtenstein states that the egg, which is attached to the bark of *Quercus coccifera*, produces at the end of April an apterous form which he terms the *foundress*. This changes its skin four times, and then produces asexually egg-like bodies (*pseudova*), which it attaches to the petiole and lower surface of the leaves. These pseudova produce the first larval form, which is apterous and larger than any of the succeeding forms. It gives origin to the second larval form, which acquires wings and migrates in May to another species of oak (*Quercus pubescens*), under the leaves of which it settles, then produces egg-like bodies, from which the third larval form originates. This is apterous and viviparous, producing its like by internal gemmation, and this process may be continued several times. It is this third larval form the reproduction of which was observed by the writers above cited. Towards the autumn a fourth larval form appears, which acquires wings and returns to the *Quercus coccifera*, where its progeny consists of larvae which develop into sexually perfect male and female insects, which also have the rostrum suppressed. The females produce a single large egg. M. Lichtenstein's observations upon other species seem to show that analogous processes of reproduction prevail widely among the Aphides, but how far this may be the case is at present doubtful. The whole question is one of great interest, and one to the solution of which any person possessing leisure and patience might easily contribute. The history of the Aphides also presents many other points of interest, and the beautiful monograph of the British species by Mr. Buckton published by the Ray Society will greatly facilitate its study.

FAMILY XIX.—COCCIDÆ.

This family, chiefly formed by the Coccineal insects and their allies, is a curious one, and in some respects differs greatly from all the other Rhynchota. The Coccidæ usually have beaded antennæ, composed of six or more joints; they have two-jointed tarsi; the wings are generally wanting in the females, and the hind wings in the males, which also have the rostrum suppressed. The metamorphosis is peculiar. The larvae are small, tortoise-like creatures, which run about freely upon the plants which they frequent. When full grown, the females without any particular change of

form attach themselves by the rostrum to some juicy part of the plant; while the male larvæ, which frequently betake themselves to the more solid portions, undergo a process of change which is peculiar to them among the Rhynchota. Beneath the scale-like skin of the larva the male insect becomes converted into a resting pupa, and the first indication of his being ready to emerge is the protrusion, from the hinder part of the protecting scale, of a pair of fine white caudal bristles. The male then soon makes his escape, coming out of his case backwards, so that the two delicate wings with which he is provided are pulled up completely over his head. He is a rather elegant creature, with a pair of perfect wings, the hind wings being represented by a sort of halteres; but his partner, making good use of the ample supply of nourishment at her command, has in the



COCHINEAL INSECT.

meantime become rather obese, and may be found adhering to the shoots of the plant, with scarcely any recognisable trace even of the original segmentation of her body. In most cases, in fact, the females might be taken for excrescences of the plant rather than insects. When numerous, the females often do much injury to cultivated plants and trees. Thus *Lecanium hesperidum* attacks the orange, and another species (*Coccus adonidum*) is often mischievous in hot-houses. They are known to gardeners as Scale-insects, or, shortly, as "the Scale." The female, after fertilisation, deposits her eggs between the lower surface of her body and the surface on which she rests. As the eggs are extruded the body of the mother shrinks, until her dried integuments serve as a protective covering to the mass of eggs.

If some of the species are injurious, others have proved of much value to mankind, such as the true Cochineal insect (*Coccus cacti*), a native of Mexico, which furnishes the most valuable and durable red dye that we possess, and the Lac insect (*Coccus lacca*), an East Indian insect, which produces the well-known lac-dye, and also by its punctures causes the exudation from the trees of the resinous substance shellac. The former feeds on a cactus, the latter on the Indian fig and some other trees. *Porphyrophora polonica* lives on the roots of a *Scleranthus* in Germany and Poland, and was much esteemed as a red dye before cochineal was generally known in Europe. Many of these insects show a white coating on their surface, and this attains a remarkable development in a peculiar species which is common on nettles, and called *Dorthesia urticae*. The female is so covered with the white secretion that it looks like a little piece of chalk. The female of this insect is active throughout its life. In *Alexandres chelidonii* both sexes possess four wings, and this insect forms a very clear transition towards the Aphides. It is common on the greater celandine (*Chelidonium majus*).

SUB-ORDER III.—PEDICULINA.

The Pediculina, or true Lice, form the last and lowest group of the Rhynchota, of which they must be regarded as very degenerate forms. They have no wings; the thorax is small, and its segments are not very distinct; the abdomen is oval, and composed of nine segments; the antennæ consist of five joints; the eyes are small and simple; and the six legs are well developed, with two-jointed tarsi, the first joint being small, and the second larger and claw-like, and folded back upon the first like the blade of a knife upon its haft. The mouth consists of a fleshy sheath (the labium),

furnished at the end with two rows of minute horny hooklets, and enclosing a much finer protrusible tube, probably representing the other parts of the mouth, and the whole is so completely retractile that when not in use nothing can be seen of any part.

These insects constitute a single family (Pediculidæ), and are all parasitic upon various Mammalia, each species being usually confined to some particular animal. They crawl about among the hairs of their host, to which they readily cling by means of the clasping tarsi. They live upon the blood which they suck from its tissues. The females attach their eggs to the hairs near their insertion into the skin. In the case of the common Louse of the human head, the young are hatched in about nine days, and take about eighteen days to attain their full growth. The known species are not very numerous, probably in part owing to the disagreeable associations attaching to the very name of these insects. Man is subject to the attacks of three, if not four species, namely, *Pediculus capitis*, inhabiting the head; *P. vestimenti*, infesting the clothed surface of the body, and *Phthirus pubis*, which is also a body Louse, but is confined to particular regions. The fourth species is the *Pediculus tabescentium*, which has been described as occasionally appearing upon a patient in immense numbers, and producing a disease known to the ancients as phthiriasis, and said to have been sometimes fatal. In all cases the best mode of getting rid of such unwelcome guests is a thorough application of oil of turpentine or some other essential oil.



PEDICULUS CAPITIS.

CHAPTER XIV.

ORDER ORTHOPTERA.

ORTHOPTERA—Characters—Structure—Internal Structure—Metamorphoses—Distribution—Classification—**THE ORTHOPTERA GENUINA**—**TRIBE SALTATORIA**—**THE GRYLLIDÆ, OR CRICKETS**—The House Cricket—The Field Cricket—The Mole Cricket—**THE LOCUSTIDÆ**—The Great Green Grasshopper—**THE ACRIDIDÆ, OR GRASSHOPPERS**—Locusts—**TRIBE CURSORIA**—**THE MANTIDÆ**—Praying Insects—**SOOTHISAYERS**—**THE PHASMIDÆ, OR WALKING STICKS**—Walking Leaves—**THE BLATTIDÆ, OR COCKROACHES**—The Common Cockroach—The Gigantic Cockroach, or “Drummer”—**TRIBE EUPLEXOPTERA**—**THE FORFICULIDÆ, OR EARWIGS**—**THE PSEUDONEUROPTERA**—**TRIBE SOCIALIA**—**THE TERMITIDÆ, OR WHITE ANTS**—**TRIBE CORRODENTIA**—**THE EMBIIDIDÆ**—**THE PSOCIDÆ**—**TRIBE PLECOPTERA**—**THE PERLIDÆ**—The Stone Fly—**Pteronarcyæ**—**TRIBE SUBULICORNIA**—**THE EPHEMERIDÆ, OR DAY FLIES**—May Fly—**THE LIBELLULIDÆ, OR DRAGON FLIES**—**THE PHYSOPODA**—Thrips—**THE MALLOPHAGA**—**THE THYSANURA**—Lepisma—**THE COLLEMBOLA**—Spring-tails—Podura.

THE Orthoptera, as already stated, include all the forms of insects with an imperfect metamorphosis and a biting mouth, of which the parts are exposed so as to be more or less recognisable externally; they have frequently appendages at the extremity of the abdomen, but these never serve as locomotive organs, as is usually the case in the following order. The members of the order, however, present so much diversity of character that there is but little to be said about the group in general: in fact, it may be a question whether the differences presented by the various subordinate types are not really in part of ordinal value; indeed, some of them have actually been formed into distinct orders by different entomologists.

There is, however, one peculiarity characteristic of all but certain low and aberrant forms of the order, namely, the division of the lower lip (*labium*). This organ in the most typical forms shows four, or in other cases two, distinct lobes in front, and the ligular part behind these is left in the middle, so that the precise equivalence of the labium to a second pair of maxillæ is at once apparent (see figure on p. 119); even when the parts are not so distinct as is here shown, there is always an indication of the median cleft, showing that the labium is composed of a pair of maxilliform organs. In the Dragon Flies we find this structure somewhat masked, but it is still recognisable by careful study; and various modifications of the organ occur in other groups. The maxillæ generally have a distinct outer lobe, known as the *galea* (or helmet), from the mode in which it overtops the inner biting lobe; the maxillary palpi are usually well developed, and composed of five, or even seven, joints. The eyes are usually of moderate or large size, but sometimes represented by an aggregation of simple eyes on the sides of the head; the ocelli are seldom wanting,

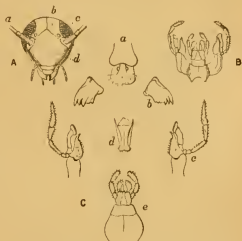
and when present they are more frequently three than two in number. In the antennæ we find the same difference as in the Rhynchota, these organs being either long and thin, generally thread-like or bristle-shaped, and composed of numerous joints, or small organs, consisting of two or three basal joints and a bristle, which, however, may be jointed.

In the structure of the thorax there is considerable difference, although the three segments are generally separate. The prothorax is frequently of large size, forming the principal part of the thorax as seen from above, but sometimes it is, much reduced, representing a sort of ring like neck; the meso- and metathorax are well developed, and in the great majority of the species are furnished with wings. These latter organs are entirely wanting in the parasitic forms that we refer to the order, and in a few members of other groups; but in general we find four wings, which, however, differ greatly in texture. Thus in one large section of the order the fore wings are of a leathery or horny consistence, generally forming protective coverings (*tegmina*) for the hind wings, which are more membranous, and in which the veins radiate from a central point to the margin, so that in repose the wings fold together after the manner of a fan; whilst in another great division both pairs of wings are membranous, and serve as organs of flight, and the veining of both pairs is more or less alike. The legs are very various in their character.

Like the labium, the abdomen shows in its structure traces of approximation to the ideal type of insects, inasmuch as in many cases this part of the body shows the whole number of eleven segments (see Fig. 2, p. 282, Vol. V.). The extremity of the abdomen is often furnished with appendages of various kinds, sometimes with long and slender bristles, sometimes with stouter jointed tails (*cerci*), and occasionally with horny processes, which may take on the form of forceps. In some forms the abdomen of the female is furnished with an ovipositor, which represents the ventral plate of the ninth abdominal segment, the genital and anal orifices being here separated, and placed, the former in the ninth, the latter in the eleventh segment.

Of the internal structure of the Orthoptera in general we can say but little. The intestinal canal (see figure on p. 120) is rarely much longer than the body. The œsophagus is followed by a gizzard, or proventriculus, chiefly in those forms which live upon an animal or mixed diet, and the salivary glands are more highly developed in the same species. In most Orthoptera the Malpighian vessels are short and numerous. The ventral nervous chain follows the generalised type of the segmentation of the abdomen, the abdominal ganglia, as well as the thoracic, being distinct, and united only by commissures, except at the extremity of the chain, where two or more of the abdominal ganglia are united into a mass. A remarkable character of this ventral chain is that it is so long that if stretched out it would extend beyond the abdomen, and it consequently forms one or more curves in its course through the body. The tracheæ are frequently dilated into air-vesicles in those forms which possess much power of flight.

Of the preparatory stages of these insects little need be said. The parasitic and apterous forms appear to undergo no changes of consequence, and the larvæ of a great number of the higher types are almost exactly like their parents, except for their smaller size and the absence of wings. In some cases, however, including nearly all the forms which pass their preparatory stages in the water, there is rather more difference between the larva and the perfect insect, although the former is still active in all its stages. In all the development is quite gradual; the young larvæ are destitute of any traces of wings, which, however, soon make their appearance beneath the skin behind the prothorax, and go on increasing in size with each moult, until the final change takes place. During this process the number of joints in the antennæ, and the number of facets in the compound eyes, usually increase with each change of skin. The larvæ seek the same diet as the perfect insects, and are generally exceedingly voracious.



HEAD AND MOUTH ORGANS OF COCKROACH.
(After Griffith and Hough.)

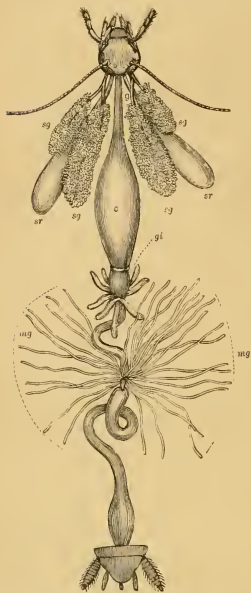
A, head (from before); a, antennæ cut off; b, epinotum; c, eye; d, clypeus. B, under portions. C, mouth organs; a, labrum; b, mandibles; c, maxillæ; d, internal tongue; e, labium.

The geographical distribution of the Orthoptera is very wide, no family being strictly confined to the warmer regions of the earth, but all extending their range at least as far as the south of Europe, and most of them having representatives in much higher latitudes. Neverthe-

less, even of those groups which are best represented in cold and temperate climates, the species are usually far larger and more numerous in warm and tropical countries, to which, indeed, some of the families are chiefly confined. The total number of known species may be estimated at about 6,000.

We have already seen that in certain structural characters the Orthoptera remarkably approach what may be imagined to be the original type of "the Insect," and it is therefore not surprising to find that Orthoptera are the very earliest types of insects that have been discovered in the fossil state. In Devonian rocks in America remains of various forms belonging to this order, and especially to its most generalised and central type—that of the Cockroaches—have been met with, together with others which certainly seem most nearly related to the forms with veined membranous wings, constituting our second subordinate group; similar types occur in the Carboniferous and Permian formations on both sides of the Atlantic; and others gradually make their appearance, showing characters which enable them to be referred to existing families, such as the beautifully preserved Dragon Flies of Solenhofen, and numerous other forms which are met with in a more or less imperfect state in Secondary rocks. In the Tertiaries they become still more numerous, and still more closely allied to the living forms.

It is somewhat difficult to hit upon a satisfactory classification of these insects, but the following will serve our purpose of indicating the alliances of the different types. We divide the Orthoptera as here understood into four sub-orders, of which the first (ORTHOPTERA GENUINA) includes the forms upon which the order Orthoptera was originally founded by Latreille. A second group, PSEUDONEUROPTERA, is formed by the membranous-winged types formerly referred to the order Neuroptera. The order is completed by two groups of small insects, namely, the PHY-



ALIMENTARY CANAL OF COCKROACH.

g, oesophagus; c, crop; gi, gizzard; mg, malpighian glands; sg, salivary glands; sr, salivary receptacles.

position of which is somewhat doubtful) and the MALLOPHAGA, which may be described as mandibulate lice. The comprehension of the sub-orders and tribes into which we propose to divide the Orthoptera will be facilitated by the following tabular arrangement:—

I.—With Wings (except in a few forms).

A. Mouth of ordinary construction:—

1. Fore wings horny or leathery (*tegmina*)
 - a. Hind wings with veins radiating from the base, fan-like:—
 - * Hind legs formed for leaping
 - † Hind legs formed for walking
 - β. Hind wings with veins radiating from the apex of a horny piece occupying the base of the anterior margin

Sub-order 1.—ORTHOPTERA GENUINA

Tribe 1.—SALTATORIA.

„ 2.—CURSORIA.

„ 3.—EUPLEXOPTERA.

2. Wings all membranous
- a. Wings, with few and simple veins, and those of the disc obsolete; tarsi 4-jointed; living in societies.
 - b. Wings with few and simple veins, all horny; tarsi 2- or 3-jointed
 - c. Wings reticulated:—
 - * Antennæ long; hind wings folded in repose
 - † Antennæ short; hind wings not folded in repose
- B. Mouth resembling a rostrum; mandibles bristle-like; wings narrow and fringed
- II.—No wings or metamorphoses; Parasites
- Sub-order 2.—PSEUDONEUROPTERA.
- Tribe 1.—SOCIALIA.
- „ 2.—CORRODENTIA.
- „ 3.—PLECOPTERA.
- „ 4.—SCUTICORNA.
- Sub-order 3.—PHYSOPODA.
- „ 4.—MALLOPHAGA.

SUB-ORDER I.—ORTHOPTERA GENUINA.

This sub-order, as already stated, represents the order Orthoptera of the older entomologists. The group is characterised by the texture of the wings, which are rarely wanting in the perfect insects; the fore wings being of a leathery consistence, and serving as a protective covering for the hind wings when folded up, after the fashion of the elytra of Beetles; and the hind wings, the sole or principal organs of flight, showing a number of strong primary veins, which radiate from a central point like the sticks of a fan, and between these generally a reticulation of finer veinlets. The head is always of considerable size, and the parts of the mouth powerfully developed, the mandibles being strong, and having their inner margins strongly toothed, and the maxillæ large, and terminating in two principal lobes, of which the outer one (*galea*) usually overtops the inner one. The maxillary palpi consist of five, and the labial palpi of three joints. The eyes are usually large, and often prominent; the ocelli are frequently altogether wanting, but when present they are generally three in number. In the development of the legs there is considerable diversity, these organs being sometimes long and slender, sometimes of moderate length and stouter; the fore legs are sometimes converted into raptorial or fossorial organs, and the hindmost pair often form powerful leaping limbs. At the end of the abdomen, in the females of many species, we find an ovipositor, and this part is also most commonly furnished, in one or both sexes, with peculiar styles, or with longer, jointed, tail-like organs, which are called *cerci*.

These true Orthoptera may be readily divided into three tribes (see Table, p. 120), namely, the Leapers, or SALTATORIA; the Runners, or CURSORIA; and the Earwigs, or EUPLEUROPTERA.

TRIBE SALTATORIA.

Contrary to the usual practice of entomologists, we have commenced with the Saltatorial Orthoptera, our object in so doing being to bring as near together as possible in the middle of the order the Cockroaches and White Ants, which are not only nearly related, and thus form the link between the two sub-orders Orthoptera and Pseudoneuroptera, but are also the most generalised types round which the others group themselves.

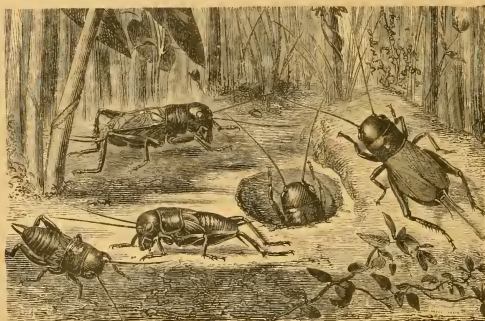
The most striking character of the present tribe—namely, the adaptation of the hind legs to the purpose of leaping—has been already indicated; they have also a large head, and a large, usually saddle-shaped pronotum; and the wings and elytra are generally well developed, frequently extending far beyond the apex of the abdomen. The males of most of the species possess the faculty of producing loud chirping sounds, but the means by which this is effected vary in the different families.

FAMILY I.—GRYLLIDÆ.

In this family, which includes the well-known Domestic Cricket and its allies, the general form of the body is usually more or less cylindrical; the head is large and prominent, with a pair of elliptical eyes, and with or without ocelli; the antennæ are bristle-shaped; and the organs of the mouth powerful. In the latter the development of the outer lobe of the maxillæ (*galea*) is variable. In some forms the *galea* is so large as to cover the whole of the inner, or masticatory lobe; in others it is narrow, and merely accompanies the inner lobe. It is interesting to find these peculiarities reflected in the corresponding anterior lobes of the labium. In the types with a large *galea*, the outer labial lobes are so broad that they nearly meet in the middle line, the two inner lobes

being thus pushed out of sight, and the labium appearing to be two-lobed in front; in those with a slender galea, the four lobes of the labium are visible. The legs of the first pair are sometimes converted into fossorial organs, sometimes adapted only for walking or running; and those of the hind pair are generally less elongated than in the succeeding families; the tarsi are generally of three joints, sometimes fewer. The fore wings, or tegmina, lie horizontally upon the back of the abdomen, covering each other more or less towards the base, and usually have a sort of fold at the outer margin, by which they embrace the sides of the abdomen; the wings, which are ample, can be folded into a very small compass, but the extremity of the anterior part of them, which is often marked off from the rest of the wing, is gathered or twisted into a sort of tail, which projects beyond the tegmina and the end of the abdomen. The wings are rarely wanting. The abdomen itself shows nine distinct dorsal and eight ventral half segments, and at its extremity a pair of long, many-jointed cerci. The females of some genera also possess a long, slender, cylindrical ovipositor, which has a slight swelling at its extremity. A curious fact relating to these insects is that the fecundation of the females is effected by the agency of spermatophores of peculiar construction.

As most people are aware, by their experience of the common House Cricket, the males of these animals are endowed with an uncommon power of noise-making. The stridulation in the case of all the musical species of this family is effected by the rubbing of the tegmina over one another, in a



METAMORPHOSES OF *GRILLUS CAMPESTRIS*.

manner so well described by Professor Westwood, that we cannot do better than borrow his words. He says—"In the males of the House and Field Crickets, on the internal margin, about one-third of its length from the base, a thickened point is observed, from whence several strong veins diverge, forming an angle from this point. The strongest of these veins, which runs towards the base of the left wing-cover, is found on the under side to be regularly notched transversely, like a file; when

the wing-covers are closed, this oblique base of the wing-cover lies upon the upper surface of the corresponding part of the right wing-cover; and when a tremulous motion is imparted to the wing-covers, this bar rubs against the corresponding bar of the right wing-cover, and thus produces a vibration, which is communicated to the other parts of the wing-covers, which, being divided into a number of irregular spaces, have each a distinct vibration, and produce a separate sound," the combination of which produces the well-known stridulation. During this operation the wing-covers of the male Cricket are considerably raised, and the insect presents a very remarkable appearance. The members of this family are not very numerous, but they occur in all the warmer and temperate parts of the earth; and although in hot countries the species are certainly more numerous, they are not generally distinguished from their relatives living in colder zones by larger size or finer colours. In fact, as the species are all more or less subterranean in their habits, and nocturnal in their activity, brilliant colouring is not to be expected in them, and they generally exhibit various shades of brown merging into absolute blackness, but some species show brownish-red or orange patches upon their tegmina. They appear to be tolerably omnivorous, feeding both upon animal and vegetable substances, although usually showing a preference for the former; and the gizzard is well

developed, and shows a remarkable internal armature of chitinous pieces. The Crickets fly freely at night, but their saltatorial powers are inferior to those of the other members of the tribe.

Although most of the species reside in the ground, in burrows and cavities which they dig out for themselves, they do not all possess special fossorial organs; and the family is divided into two groups, according as the fore legs are constructed for walking or digging. The well-known common House Cricket (*Gryllus domesticus*) belongs to the former section, although it burrows freely by means of its strong mandibles into the mortar between the bricks of fireplaces, ovens, &c. Living as they do in the immediate vicinity of the fire, the House Crickets seem to be independent of the changes of the seasons, and may usually be found of all ages at all periods of the year. During hot summer weather, however, they often make their way out of doors, and even in London their chirp may be heard at night, proceeding apparently from the house-tops. A nearly-allied British species is the Field Cricket (*Gryllus campestris*), which is rather larger than the House Cricket, and of a black colour, with the base of the tegmina yellow. It is a comparatively rare, or rather very local species in England, but abounds in Southern Europe. It makes burrows from six inches to a foot in depth in sunny, sandy places, using its mandibles in the operation. The insect sits in the mouth of its burrow on the look-out for passing insects, which constitute the greater part of its diet. Its chirping is much louder than that of the House Cricket, but it is particularly shy and timid, retreating to the bottom of its burrow at the least suspicion of danger. The female is said to lay about 300 large white eggs, which she deposits in the ground in a mass, glued together and to the side of the burrow by a sticky secretion. The larvæ are hatched about the end of July, and remain in the larva state through the winter. A third British species is the Wood Cricket (*Nemobius sylvestris*), which is much smaller than either of the preceding, and in which the hind wings are rudimentary. It is found abundantly among dead leaves in woods in France and other parts of the continent, but is rare and local in England. A still more remarkable species, which may be called the Ants'-nest Cricket (*Myrmecophila acervorum*), has neither tegmina nor wings, and in the broadly oval form of the body more resembles a minute Cockroach than a Cricket, a similarity which is increased by the partial concealment of the head beneath the front of the prothorax. It has, however, very strongly developed leaping posterior legs, which it uses in case of need with great effect. This curious little insect is found in France, Germany, and other parts of Europe in Ants' nests, or associated with Ants under stones. The ovipositor is short, and forked at the end.

Most of the species of this first division of the family agree in general characters with the common House Crickets and Field Crickets. They have ambulatory front legs, the females have an ovipositor, and the ocelli are usually deficient. In the second group, the members of which are generally more exclusively subterranean in their habits, living habitually, like the Mole, in galleries and chambers which they dig out in the ground, not only are the front legs converted into special digging organs, but the females have no ovipositor, and the crown of the head has generally two or three ocelli. Their organisation is in many respects very singular, and it is remarkable that they are as widely distributed over the earth's surface as their more normally constructed relatives. The British Mole Cricket (*Gryllotalpa vulgaris*), which may be taken as a type of the whole group, is a large robust insect over an inch and a half in length, of a dark brown colour, with a very large ovate prothorax, and short, irregularly oval tegmina, beyond which and the apex of the abdomen the wings extend far when folded up. In the character of the fore legs, the insect presents a singular analogy with the Moles. These limbs are very stout, and articulated in such a manner that they are thrown out from the sides of the prothorax in the most convenient position for digging, and the tibiæ, which constitute the actual digging parts, are flattened transversely to the axis of the body, triangular in form, and terminated by four finger-like processes. The tarsi are inserted near the end of the outer margin of the tibiæ, and are short and stout. Owing to the great amount of force necessary to work these implements, the muscles connected with them are very greatly developed, and this explains the large size of the prothorax in which they are contained, and which also possesses a remarkable internal framework of processes for the attachment of these muscles. The insect in burrowing is said to exert a force equal to two or three pounds. Like the Mole, it passes along close beneath the surface of the ground, and often raises a small ridge as it advances. It frequents gardens, especially near the banks of canals and other pieces of water, and also moist meadows, and is described as frequently causing

considerable damage to vegetation by cutting through the roots of plants which come in its way, but apparently not for food, as, although it will consume vegetable substances, its diet consists chiefly of underground insects and worms. The Mole Cricket flies occasionally in an irregular, undulating course in the evening, and its stridulation produces a dull, jarring note, which has been compared to that of the Goatsucker. The eggs, to the number of 200 or 300, are deposited in a chamber of considerable size, and enclosed in a sort of cocoon-like envelope; the larvæ, when first hatched, are white, and they are said to be three years in arriving at maturity.



MOLE CRICKET.

A considerable number of species closely agreeing with the preceding in structure and habits are found in all parts of the world, but the group also includes some which depart rather widely from the common Mole Cricket. One very singular form, described as *Cylindrodes campbelli*, inhabits Melville Island, on the north coast of Australia. It is about two inches and a half long, and quite cylindrical, with the prothorax forming a third of the total length of the body, with exceedingly short legs, which can be lodged in cavities of the sides of the body, and with two-jointed tarsi. This insect burrows into the stems of plants, and causes them to wither. A true *Gryllotalpa* (*G. didactyla*), inhabiting South America and the West Indies, has often done much damage to the sugar-canes in the

same fashion. In some curious little species forming the genera *Tridactylus* and *Rhipipteryx* there are no tarsi on the hinder legs, their place being taken by two or more pointed, movable appendages. One species of *Tridactylus* (*T. variegatus*) occurs in the south of Europe, and burrows in the sand on the banks of rivers. The species of *Rhipipteryx* are from Brazil and Guiana.

FAMILY II.—LOCUSTIDÆ.

Linnaeus referred the whole of the Saltatorial Orthoptera to his genus *Gryllus*, which he divided into sub-genera, and gave to each of these an appropriate name. His sub-genus *Locusta* included the species of the following family, among which the true Locusts find their place; but, unfortunately, Fabricius, when forming these groups into separate genera, thought fit to apply the name of *Locusta* to the genus containing the species constituting the present family, and in this course he has been since followed by the majority of entomologists. It is now too late, and would give rise to many embarrassing questions, to revert to the more sensible nomenclature of Linnaeus, and we must continue to regard the insects, to which in common parlance the name of Locusts is applied, as not belonging to the family Locustidæ.

The insects so denominated by entomologists present a very considerable variety of form and character, but, like the rest of the Saltatoria, they have a large head, placed vertically in front of the prothorax, and a mouth furnished with powerful jaws. The ocelli are almost always wanting; the antennæ are very long, thin, and bristle-shaped; the labrum is nearly circular, and the inner lobes

of the labium are very narrow, and usually displaced by the enlarged outer lobes; the prothorax is saddle-shaped; the hind legs are usually much elongated; and the tarsi are four-jointed. The two pairs of wings are almost always developed, and they are placed in repose almost perpendicularly on the sides of the body, which they generally exceed in length; the tegmina overlap each other only by a small portion of the inner margin towards the base, and here in the males are situated the stridulating organs, consisting of a peculiar tale-like plate, surrounded by elevated chitinous ridges in the right, and a corresponding space with strong veins on the under surface of the left wing-cover, which overlies the other, and by the friction of these parts a loud chirping is produced. The dorsal surface of the abdomen usually shows the whole of the eleven segments composing that part of the body—at any rate, in the females—which are also furnished with a long, sabre-like ovipositor; in both sexes we find at the end of the abdomen a pair of unjointed appendages. (Fig. 2, p. 282, Vol. V.)

The Locustidæ not only possess a very considerable power of making a noise in the world, but they are also among the comparatively few insects in which a special organ for the perception of sounds appears to exist. The supposed auditory organs in these animals consist of a pair of apertures situated at the base of each anterior tibia; these are closed by tense membranes, between which the main trachea



LOCUSTA VIRIDISSIMA AND ITS METAMORPHOSES.

of the limb is dilated into a vesicular form, whilst at the same point a nerve originating from the first thoracic ganglion terminates in a swelling, which gives off a set of peculiar nerve elements, enclosed in small transparent vesicles.

In temperate climates, the adult Locustidæ make their appearance late in the summer or in the autumn; some of them live among herbage on the ground, but the majority frequent trees and bushes. They feed chiefly upon other insects and their larvæ, although vegetable matters appear to form part of their diet. The gizzard is always present, although less highly developed than in the Crickets. Although most of the species are abundantly provided with wings, they do not seem to fly readily, but make use of their wings more after the fashion of a parachute, to support them in the air when making what may be denominated long leaps. The females deposit their eggs in light soil by means of the long ovipositor, which is pushed down into the ground, and then allows the eggs to pass out one by one by the separation of its two valves.

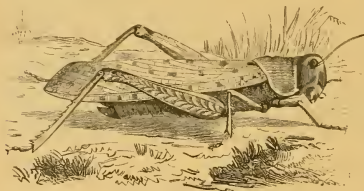
The Locustidæ form a much more extensive family than the Gryllidæ, and they are also very widely distributed, although they are more especially inhabitants of the warmer regions of the earth's surface. In hot countries, indeed, the species are not only much more numerous, but for the most part larger and finer than in temperate climates, although some of the European species are of considerable size. Thus the Great Green Grasshopper—*Locusta viridissima*, as it is called—measures over an inch long in the body; and another European and British form, the *Decticus*

errucivorus, is of the same length. The former insect is found in many parts of the country in meadows, but it also goes freely upon trees and shrubs; the latter is more particularly a ground-loving species. It receives its name from the custom prevailing among the Swedish peasants of making it bite their warts. The insect, in common with many other Grasshoppers, when at all roughly handled, emits from the mouth a brownish fluid which is said to possess acrid qualities, and the introduction of this into the warts is supposed to cause their disappearance.

The forehead in most species of this family is more or less prominent, but in those of the genus *Conocéphalus* this part is produced into a conical process, which projects forward between the antennæ; and in *Copiphora* it forms a very pointed cone which stands up perpendicularly from the head. The females in the last-named genus, the species of which inhabit South America, are remarkable for the length of the ovipositor; in *Copiphora cornuta*, the body is about one inch and a quarter, and the ovipositor two inches long. The general colour of the species, especially of those which live upon trees and shrubs, is green, which renders their detection in their leafy abode very difficult, but in certain tropical genera (such as *Phyllophora* and *Phylloptera*), this difficulty is increased by the form of the wing-cases, which are broad and flat, placed very nearly perpendicularly upon the sides of the body, and traversed by a strong median vein, from which other smaller veins appear to spring after the fashion of the veins of a leaf. The resemblance to particular leaves is so striking that the species are named from it, and we have *Phylloptera laurifolia*, *P. myrtifolia*, *Pseudophyllus neriifolius*, &c. These are all tropical species.

FAMILY III.—ACRIDIDÆ.*

This family, which includes the common Grasshoppers and true Locusts, is easily distinguished from both the preceding by the character of the antennæ, these organs being short, less than half the length of the body, generally thread-like, or even more or less thickened towards the tip. The



MIGRATORY LOCUST (*Eidipoda migratoria*).

insects are generally of a stouter form than the Locustidæ, and have the body compressed at the sides. The head is similar in its general character to that of the Locustidæ, but it has almost always three ocelli upon the forehead; the organs of the mouth, especially the mandibles, are strong; the labrum is very large and notched in the middle; and the inner lobes of the labium are much reduced in size and concealed by the outer ones. The pronotum usually shows three longitudinal ridges, and is more or less produced behind; the tegmina are narrow

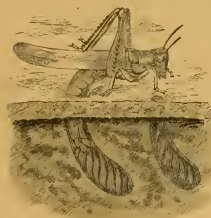
and roof-like, and those of the males contain no special stridulating organs, the well-known chirping of these insects being produced by a different arrangement; the hind legs are elongated; the tarsi are of three joints; and there is no projecting ovipositor in the females.

The song of the male Grasshopper, which must be familiar to every one who has walked through fields in the summer, is produced by the friction of the hinder thighs against the wing-cases. The insect stands upon his four ambulatory legs, and works the hind legs alternately up and down on each side of the body, so that the inside of the thighs passes rapidly over the veins of the wing-cases. Dr. Landois finds towards the lower surface of the inside of each thigh a small elevated ridge, upon which there is a row of minute lancet-shaped teeth, and it is apparently the friction of these little points against the strong veins of the corresponding part of the tegmina that gives origin to the chirping sound. Burmeister says that the females also possess the power of chirping, but this would appear to be a mistake, although they may be observed occasionally performing the same movements of the limbs by which the males produce their sounds; at the same time, it is to be remarked that even the males of some species exercise themselves in the same way without effect so far as our ears are concerned, and yet Colonel Goureau was of opinion that they may be audible to

their companions. The Acridiidae are provided with peculiar organs to which we may with some confidence ascribe auditory functions. These are two apertures of considerable size situated in the first segment of the abdomen, closed by a membrane stretched upon a chitinous ring, and having upon its inner surface certain chitinous pieces, one of which terminates in a delicate vesicle filled with a transparent fluid, and terminating in two branches. A nerve proceeding from the metathoracic ganglion runs to this apparatus, forms a ganglionic swelling in juxtaposition with the membrane, and another in contact with the delicate vesicle, and both these ganglia give origin to fine nervous rods such as are characteristic of sense-organs. From the structure of this complicated apparatus there seems to be no doubt about its function, which, however, was long a puzzle to entomologists.

The food of the Acridiidae appears to be exclusively of a vegetable nature, and in accordance with this we find that the gizzard is not developed. The insects are, however, exceedingly voracious, and when they occur in great numbers, as in the well-known invasions of Locusts, they do much damage in cultivated ground. They generally possess great leaping powers, and also fly much better than most of the other Saltatoria, although, as a rule, their flights are of short duration. Many of the larger species, however, rise to a considerable height in the air, and fly to greater distances.

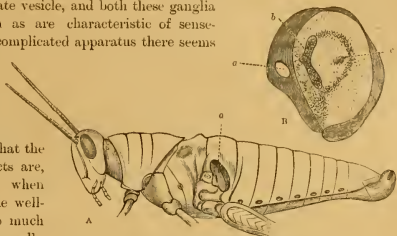
As already stated, the female Acridiidae possess no exerted ovipositors, but they nevertheless deposit their eggs in the ground in regular cavities prepared for their reception, and in the formation of these receptacles the parts homologous with the valves of the ovipositor in the Locustidae play an important part in conjunction with the pair of organs representing the cerci. The former are



FEMALE LOCUST DEPOSITING EGGS.
(After Bulletin of U.S. Entomological Commission.)

manner that the heads of the young larvæ are directed upwards, and these, when hatched, push their way out either through the spongy material, and so up to the entrance of the cavity or directly through the ground.

The British species of this family, although they are able to make the fields vocal during the summer, are not very numerous, nor are they of very large size. On the continent of Europe, however, even in the latitude of England, several larger species occur, and in warmer regions we find quite gigantic forms, some of the Brazilian *Acridia* reaching seven or eight inches in expanse of wing. The species, whose ravages have given the name of Locust an unenviable notoriety, are not, however, of



AUDITORY APPARATUS OF GRASSHOPPER.

A, figure showing position of apparatus; a, tympanum; B, external surface of apparatus (left enter ear); a, aperture of the strum in the raised rim of the tympanum; b, the larger horn-like projection seen through the semi-transparent tympanum; c, the smaller horn-like projection.

such very large size, the females of the best-known Locusts of the Old World being only about two inches long, while the Rocky Mountain Locust (*Caloptenus spretus*) of North America is only about the size of the largest English Grasshoppers. In European countries the Migratory Locust (*Edipoda migratoria*) is the best known, and this sometimes strays as far as Britain. In the south-east of Europe a nearly allied species (*Edipoda cinerascens*) occurs. These insects are excessively destructive to vegetation when they make their appearance in unusual abundance. They travel more or less in search of nourishment while still in the larval condition, but their great wanderings are performed through the air after they have attained the perfect state. The most extraordinary accounts are on record of the vastness of the swarms of Locusts which every now and then invade particular districts; they are said sometimes absolutely to darken the sun at noon. They clear everything off the surface of the ground as completely as if the place had been visited by fire (whence the name of "Locust" applied to them). They have on several occasions caused disastrous famines in certain countries, and the putrefaction of their bodies *en masse*, especially on the sea-shore, is described as giving origin to most offensive and pestilential effluvia. The range of these destroyers in the Old World stretches from Spain and the south of France in the west, through southern and central Russia to China; south of this boundary the Locusts have repeatedly done much injury to the crops. In America more or less migratory Locusts are described as committing devastations quite up into Canada. In Eastern countries Locusts are commonly eaten.

TRIBE CURSORIA.

The insects forming this tribe are at once distinguished from those of the preceding families by having the hind legs adapted for walking or running and not for leaping; and from those of the next tribe by the veining of the wings, the central point of radiation of the veins being here placed at the root of the wing. By some entomologists they are treated as constituting two or even three separate tribes, each including only a single family, but this course seems to be quite unnecessary.

FAMILY IV.—MANTIDÆ.

The Mantidæ are at once distinguishable from the insects of the two following families by the structure of their fore legs, which are converted into powerful raptorial organs, in correlation with which the prothorax is also generally much elongated. The coxæ of these limbs are inserted far forward on the under surface of the prothorax, and are very long, reaching, in fact, as far as the base of that segment. Attached to them, with the assistance of a well-developed trochanter, are the femora, which are long, generally stout, and deeply furrowed along the under side, the edges of the furrow being garnished with rows of strong spines; the tibiæ which follow are more slender, but are also strongly armed with spines on the under side, and they are hinged on to the end of the femora in such a way that they can shut into the groove which, as already stated, runs along the lower surface of the latter. As the elongated prothorax can be raised into a nearly vertical position, and the coxæ are very freely articulated, it will be seen that these fore limbs constitute most formidable prehensile organs, from which any small animal seized by them would not have the least chance of escaping. The other four legs are much more slender and organised for walking; the tarsi are all five-jointed.

The body in these insects is more or less elongated; the head, which is triangular or heart-shaped, is attached to the thorax by a distinct neck, and set on vertically; the eyes are oval, usually of considerable size, and inflated, and between them on the forehead, behind the insertion of the antennæ, are three ocelli, which are more distinct in the males than in the females. The parts of the mouth are well developed, and the four lobes of the labium are almost equal in size. The antennæ are generally slender and thread-like, and composed of numerous joints, but variable in length.

The tegmina and wings are generally well developed, reaching or passing the extremity of the abdomen, upon which they are placed horizontally, the tegmina lying one over the other. The latter organs have a very distinct marginal area cut off by a strong vein, and from this veins run to the inner margin, and usually give off numerous fine veinlets which traverse the membrane. The wings show the usual fan-like arrangement of veins characteristic of the tribe. The abdomen is usually elongated, wider towards the extremity, and broader in the females than in the males;

sometimes it is enlarged at the sides. There are eight or nine dorsal segments in the males and one less in the females; the extremity of the abdomen in both sexes is furnished with a pair of jointed cerci.

The species of this family, which are generally of considerable size, those of an inch long being comparatively small, are almost entirely inhabitants of the warmer regions of the world, only a few being found in Southern Europe, and these also occur in Africa. The three most abundant European forms, met with not uncommonly in the south of France, are *Empusa pauperata*,



EMPUSA PAUPERATA AND ITS METAMORPHOSES.

with toothed antennæ, which measures from two to two and a half inches in length; *Mantis religiosa*, a species of equal size with simple antennæ; and a smaller species allied to the latter (*Mantis oratoria*). These insects are remarkable enough by their form, but many exotic species are much more curious. A very considerable number have some parts, especially the femora, dilated into leaf-like pieces, often of singular form; in others the prothorax is widened into a broad leaf-like plate, or some portion of the abdomen has its margins dilated in the same fashion. The colours displayed by many species when alive are exceedingly beautiful, especially the very delicate grass-green which is the general colour of a great number. The hinder wings are often very brilliantly coloured, sometimes showing eye-like spots of large size. In certain desert species, such as those forming the genus *Eremophila*, the colours are, on the contrary, exceedingly sober. These last insects reside in the most barren

deserts of Arabia and North Africa, and their colour is exactly the same as that of the sand on which they run about in search of prey.

When thus engaged, the Mantidæ generally move slowly upon their four rather long and slender ambulatory legs, with the prothorax elevated and the fore legs extended, an attitude which has led to a variety of curious conceptions with regard to them on the part of the imaginative inhabitants of southern Europe. From very ancient times it has been believed that these insects would indicate by the gestures of their fore limbs the road that a wanderer ought to take; hence they were called *Mantes*, or soothsayers. Another view of their nature ascribes a religious signification to the attitudes taken by the insects, and hence they are known as praying or preaching insects, or by other names intimating a belief that they are habitually engaged in praising the Deity; and, according to an old legend, St. Francis Xavier, on seeing a Mantis moving slowly along with its fore legs raised as if in devotion, desired it to sing the praises of God, which it immediately did in a very beautiful canticle. Unfortunately, all these wonderful notions are by no means correct; the Mantis walking solemnly in a devotional attitude is really an exceedingly voracious creature in search of its prey, and the raised fore limbs are merely extended in readiness to seize its victim as soon as its stealthy pace has brought it within striking distance. Once seized, the prey has no chance of escape; the abundant armature of the femora and tibiæ hold very firmly whatever they get the opportunity of claspings. Their power is very great, and they are used, not only for grasping prey, but also in fighting among themselves, when a successful stroke will often take off an adversary's head. They can even draw blood from the fingers of a human assailant, and in all probability when the soothsayer is supposed to be kindly directing some lost child in the way to its home, the attitude suggesting this kind action is really assumed for defensive purposes.

The female Mantidæ deposit their eggs enclosed in peculiar cases which they attach to the twigs and branches of shrubs, to stones, and other objects. These egg-cases, which vary a good deal in form, are usually of a greyish-brown colour, and furrowed transversely, each furrow generally corresponding to a storey of the interior structure, of which there may be as many as twenty, and the largest of these may contain a couple of dozen eggs. Each egg is contained in a sort of cell, formed by a portion of frothy liquid ejected with it from the abdomen of the mother, and thus the central part of the case is occupied by a series of circles of such cells, each cell containing an egg, which is placed in such a manner that the head of the larva when formed will be directed towards the central axis of the case. The larvæ, when hatched, have therefore nothing to do but to make their way straight forward. The outer part of the case consists of a further portion of the same frothy liquid, which is produced as the business of egg-laying goes on, and worked into shape by means of the extremity of the abdomen. The fluid in question is at first nearly transparent, but as it hardens it gradually acquires a darker colour. The young larvæ are attached to the interior of the shell of the egg, which remains in the cell, by means of two slender silken threads which spring from their cerci, and on their first emergence they remain suspended in the air by these threads until the time of their first change of skin, after which they descend to the ground and go in search of food. This would seem to be a provision to ensure their safety during the first few days of their existence.

FAMILY V.—PHASMIDÆ, OR STICK AND LEAF INSECTS.

If many of the Mantidæ are singular-looking creatures, the majority of the members of the present family are still more *bizarre* in their appearance. Most of them resemble sticks, either green, growing twigs, or brown and withered branches, and hence the names of Stick-insects and Walking-sticks, commonly applied to them, are very appropriate. Their skeleton-like forms, often dusky colours, and slow, stealthy motions, have given origin to another similitude—they have been likened to ghosts or spectres, an idea upon which the names of the typical genus and of the family are founded.

The Phasmidæ are at once distinguishable from the Mantidæ, to which, however, they are nearly allied, by the construction of the fore legs, which are ordinary walking limbs, not adapted for seizing anything. In fact, all the legs are similar, although not of equal length; the femora and tibiæ are often dilated into foliaceous lobes; the tarsi are all five-jointed, with large arolia between the claws. The head is freely attached to the thorax, and bears a pair of thread-like

antennæ of variable length; the eyes are hemispherical, and the ocelli are either three in number or altogether wanting. The labrum is deeply notched; the mandibles are short and powerful; the maxillæ and labium are formed much as in the Mantidæ, but the outer lobes of the labium are very much larger than the inner ones. A striking contrast to the Mantidæ is found in the prothorax, which is very short; the mesothorax, on the contrary, is elongated, and is indeed the longest of the three thoracic segments.

Both tegmina and wings are often absent, either in the females or in both sexes; when developed, the former are short, and only cover a portion of the true wings, which present a remarkable structure. The front or outer portion of each wing, from the base to the apex, is of a leathery texture, resembling that of the tegmina; the membranous hinder portion of the wing shows the usual fan-like arrangement of primary veins, and the whole of this part, when shut up, is concealed beneath the leathery anterior area, which thus acts the part of a supplementary wing-cover. The abdomen shows nine segments on the back, but in the females only seven, and in the males eight rings are recognisable below, and this is due to the circumstance that in the former the last ventral plate but two, and in the latter the last but one, is usually produced so as to conceal the actual apex, which is furnished with a pair of unjointed cerci, sometimes knobbed or leaf-like in their form.



BACILLUS ROSSII.

The eggs of the Phasmodæ are few in number, and are deposited singly, the females carrying them about in the shovel-like process of the seventh abdominal half-ring for some time before quitting them. The eggs are of large size and covered with a horny shell, at one end of which there is a distinct operculum. The sides are variously ornamented with wavy lines, and the general surface is more or less punctured. In the West Indies the hatching of the eggs has been observed to take place in from seventy to one hundred days after their deposition.

The number of species of this family is not very large; by far the greater part of them are inhabitants of the warmer regions of the earth, and they seem to increase in magnitude especially the nearer their home lies to the equator. The species are much more numerous in the eastern than in the western hemisphere, and in both a few species pass into temperate regions. Two occur in the south of Europe, the best-known being Rossi's Stick-insect (*Bacillus rossii*), a brown wingless form from two inches to two inches and a half in length, found in Italy and the south of France. Some of the tropical species are the largest of insects, a winged Australian species (*Acrophylla titan*) attaining a length of ten inches, whilst an apterous Brazilian species (*Bacterius aurita*) is of equally gigantic dimensions. The general coloration of the species exhibits various shades of brown and

green, but the wings and tegmina are often variegated, and the former sometimes very beautifully coloured.

The Phasmidæ reside chiefly upon trees and bushes, the leaves of which seem to constitute their sole food. They are nocturnal in their habits, resting during the day among the twigs and branches, where their stiff and somewhat ungainly forms may easily lead to their being mistaken for dried portions of the plant. When resting, the fore legs are stretched forward at the sides of the head, for the reception of which the femora are generally bowed out near the base; the other limbs are brought close to the sides of the body, and the whole insect acquires a most unobtrusive appearance. When danger threatens also these insects will stiffen themselves, and counterfeit death. They are said to have very voracious appetites, and sometimes to do mischief to cultivated trees and plants.

Curiously enough, while the majority of the Phasmidæ simulate portions of the woody structure of the plants they frequent, a few species belonging to the East Indian region present a striking resemblance to leaves, so much so, indeed, that they were formerly supposed to be a sort of compound animal and vegetable organism, and even now cases are sometimes made up by the natives of the countries inhabited by these curious creatures, in which Walking sticks of different sizes are joined together to represent the branches of a tree, while the foliage is composed of a few Walking-leaves stuck on here and there. These Walking-leaves form the genus *Phyllium*, and they constitute one of the most singular of insect types. The head and exposed segments of the thorax form a sort of stalk, behind which the abdomen is greatly dilated in the form of a thin flat plate, nearly covered in the female by a pair of tegmina veined in such a manner that when the two are placed close together they represent a leaf with its mid-rib, and distinct veins running from the mid-rib to the margins, whilst the space between the veins is reticulated so as closely to resemble the parenchymatous portions of the leaf. The male is amply provided with wings, only partially covered by the short tegmina, and has longer antennæ than the female, in which the latter organs are very short and the wings altogether wanting. The femora are also dilated like little leaves, and the same character is presented by the front tibiae. These insects are of a green colour when alive, which often changes to a yellowish-brown tint after death; hence the best-known species has been described as *Phyllium siccifolium*.

FAMILY VI.—BLATTIDÆ, OR COCKROACHES.

This family includes the numerous species of Cockroaches, or Kakerlaks, one of which, under the name of the Blackbeetle, is but too well known to most housekeepers. They present a very considerable uniformity of general characters, the body being commonly rather flattened and of an oval form, and the head entirely, or almost entirely, concealed beneath the anterior margin of the broad and shield-like prothorax, and so placed that its crown, which rarely bears any ocelli, is directed forward. The eyes are large, and more or less kidney-shaped; the antennæ long, tapering, bristle-like, and composed of many joints; the outer lobes of the labium are considerably larger than the inner ones; the coxæ are approximated, the tibiæ spinous, and the tarsi always five-jointed. The tegmina and wings are generally developed, although sometimes abbreviated, especially in the females. When they attain their full development the tegmina overlies one another at their inner margins, and exhibit a strong vein near the outer margins, from which branches are given off on both sides. The wings show the usual fan-like arrangement of veins. The abdomen presents nine or ten dorsal and from six to eight ventral rings, and at the extremity a pair of jointed cerci.

The Blattidæ are represented in all parts of the world, but most abundantly within the tropics, and especially in America, where also the largest and finest species are to be found. They are active animals, running with considerable rapidity, but their activity is chiefly nocturnal, and during the day they generally remain quietly concealed in some obscure retreat. The introduction of a light into their haunts stops their operations, and generally causes them to run away in confusion to their holes, hence the name of "Lucifuge" has sometimes been given to them. This applies more particularly to the species which frequent houses, &c. Some of the smaller species, which live in the open air, do not show the same dread of light, although even these are generally active only at night. Their diet consists of both animal and vegetable substances, but the former seem to be



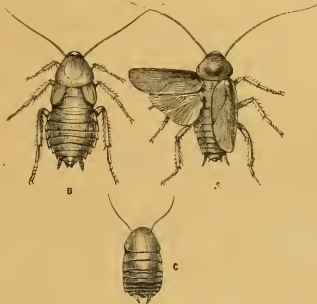
EGGS AND IMMATURE AND ADULT FORMS OF *PHYLLIUM SICCIFOLIUM*.

preferred, and the gizzard, although rather small, is thick-walled and well developed. The eggs are deposited by the females in very peculiar hard, horny capsules of an oblong form, rounded at the sides and ends, slightly grooved transversely at the interstices between the contained eggs, and slit along one side, the margins of the slit being finely toothed, with the teeth of one side accurately fitting in between those of the other. The eggs, each of which has its own thin but tough envelope, are placed in a double row within this capsule, arranged side by side in such a way that one extremity of each egg is directed towards the above-mentioned slit. In this manner the escape of the young insect is facilitated, as it has only to push straight forward, and so out of the slit, after softening a sort of cement, with which the closure of the latter is completed. The number of eggs enclosed in these capsules varies considerably in the different species; the common Cockroach of our kitchens places sixteen eggs in each capsule, but those of other species contain thirty or even forty eggs. It will be easily understood that such a capsule as this is very much out of proportion to the size of the parent insect, and the females appear to have some difficulty in getting rid of their burthen. They have been observed to run about for a long time, sometimes even for several weeks, with one end of the capsule projecting from the extremity of the abdomen. The newly-hatched young are of a pale colour, but speedily become darker. They are said to change their skin about six times.

The best-known species is the Common Cockroach, or "Blackbeetle" (*Periplaneta orientalis*), which is not a native of Europe, but is supposed to have been introduced there by commerce from the East. Whatever its origin, however, it has now made a home for itself wherever man dwells.

The males have perfect wings and wing-cases, which, however, are shorter than the abdomen; in the females the tegmina are a pair of small, ovate organs placed behind the prothorax, and the wings are quite rudimentary. Another species, which has attained a distribution almost as wide, though not so general, is the American Cockroach (*Periplaneta americana*), a native of the warmer parts of America, whence it has been carried in ships to the ports of nearly all parts of the world. It is a larger and redder species than the common Cockroach, and the tegmina and wings are fully developed, the former passing beyond the extremity of the abdomen. This insect is common on board ship, and may be almost constantly met with in the docks, especially when tropical produce is being landed. It is likely that other species have been similarly transported to new localities, and, indeed, this is known to be the case with a pale species (*Panchlora maderae*), originally described as a native of Madeira, but now found in Brazil and the East and West Indies, as well as in European ports.

Besides these undoubtedly introduced exotic forms, we have in Europe a few species which appear to be indigenous, and which, both in Britain and on the Continent, live in the open air, in woods, although they sometimes come into houses, and in some localities do considerable mischief. The best known of these may be called the German Cockroach (*Blatta germanica*), an insect about half an inch long, of a pale yellowish colour, with two blackish longitudinal bands on the pronotum. The wings and tegmina are well developed. This species is common in many parts of Europe, and in some places it has proved very troublesome in houses, and especially in breweries and distilleries. The insects are supposed by the Russians to have been introduced into their country from Germany, and thence called "Preussen." In Austria they are thought to have come from Russia, and accordingly denominated "Russen." They have also made their way into other countries. Another species of smaller size, which is common in woods on the continent of Europe, and is found in



COCKROACHES—MALE (A), FEMALE (B), AND YOUNG (C).

England on whitethorn bushes, makes its way into the dwellings of the Laplanders, and, when it occurs in great numbers, inflicts serious damage upon their stores of provisions. Hence it was described by Linnaeus as *Blatta lapponica*. Several other small allied species are met with in Great Britain, but it is to tropical America that we must go in search of the larger and finer forms. The largest of all, the Gigantic Cockroach (*Blaber gigantea*), which measures about three inches in length, is an inhabitant of South America and the West Indies, where it is known as the "Drummer," from its possessing the very inconvenient faculty of producing a noise resembling a sharp knocking with the knuckles against wainscot. This and other large species are said sometimes to devour the extremities of the dead, and even to attack people when asleep. *Blatta gigantea*, however, is a handsome insect, being of a pale yellow colour, like bone, with the head, a nearly square spot on the pronotum, and a sort of dash near the base of the tegmina black or brown. The species of *Phoraspis*, which are also American, are more convex than the ordinary run of Blattidae, and present no inconsiderable resemblance to some Beetles of the family Cassididae. One of the best-known species is the *Phoraspis picta*, a black insect rather over half an inch long, with the front margin of the pronotum pale yellow, and a red band upon each of the tegmina. These insects are described as frequenting flowers.

TRIBE EUPLEXOPTERA, OR EARWIGS.

This group, which includes the insects commonly known as Earwigs, is one that has always been a trouble to systematic entomologists. Placed with the Beetles by Linnaeus, the Earwigs were speedily removed to a more natural position, side by side with the forms that we have grouped together as Orthoptera Genuina, whilst Leach and Kirby separated them as a distinct order, to which Westwood applied the very appropriate name of Euplexoptera. There can be no question, however, about their belonging to the order Orthoptera as here adopted, nor as to their being most nearly allied to the true Orthoptera, but the opinions of entomologists are divided upon the question of treating the group as a tribe of the latter, or as a distinct group of equal value. After much hesitation we have preferred adopting the former course. They must be regarded as forming a sort of side group, allied to the Phasmodae and Blattidae.

The distinctive character of the group is found in the structure of the wings, both pairs of which are developed in all but a few species. The anterior pair (*tegmina*) are of a horny or leathery consistence, but always very much shorter than the abdomen, laid horizontally upon the back, and meeting in the middle line by a straight suture. The hind wings, on the contrary, are of large size, and composed of a very delicate membrane, with the exception of the basal portion of the anterior margin, which is leathery or parchment-like, terminating at some distance from the base in a piece of somewhat firmer texture. From this point starts a series of fine veins, which radiate in all directions to the nearly semicircular margin of the wing, from which another set of veins starts, running in the spaces between the former towards the same centre, but without reaching it. All round the hinder part of the wing, from its base to its apex, runs another vein nearly parallel to the semicircular margin, and intersecting the whole of the radiating veins, and within this the latter all show a slightly thickened portion. When folded in repose, the wings, notwithstanding their ample size, are completely packed away beneath the short tegmina, and the mode in which this is managed is as follows:—the wing folds up like a fan in the direction of the radiating veins, and it is further bent up from the end of the anterior basal leathery piece, and again folded down through the portion where the radiating veins are thickened, and when these processes are completed the wing can be comfortably concealed beneath the somewhat scanty covering furnished by the tegmina, the only part left out being the stout tip of the leathery basal piece, which nearly always projects more or less, and, to some extent, supplements the tegmina. The wings are deficient in a few species, and some of these are also destitute of the tegmina, but in these cases the insects present other characters which sufficiently indicate the group to which they belong. The tribe contains only a single family.

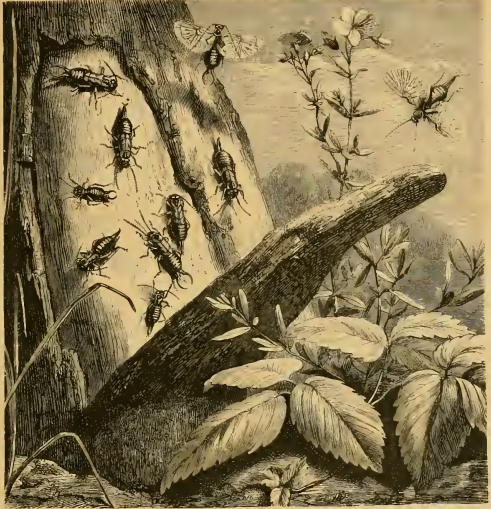
FAMILY VII.—FORFICULIDÆ.

The insects of this family present a great uniformity of structure, so that any common species may serve as a type of the whole. They have a freely projecting head, united to the prothorax by a short neck; the eyes are small and round, and there are no ocelli; the lobes of the labium are

united in pairs, so that there are only two of them; and the antennæ are thread-like, and composed of from twelve to forty joints. The characters of the wings have been already described. The tarsi are of three joints. The abdomen is considerably elongated, usually a little inclined behind, and composed of nine segments, of which, however, the seventh and eighth in the females are reduced in size, and concealed by the sixth; at the extremity, in place of the cerci present in most of the preceding families, there are two large, curved horny pieces forming a pair of forceps, which often attain formidable dimensions, especially in the males.

The exposed abdominal segments are horny on both surfaces, as in the *Brachelytrous* Beetles, to which these insects have a certain analogical resemblance. In both groups the elongated abdomen possesses considerable mobility, and is often used to help in packing the wings away beneath the wing-cases.

The Earwigs are, for the most part, crepuscular or nocturnal insects, concealing themselves during the day in crevices, under the bark of old trees, or in the ground, under stones. Their food consists almost entirely of vegetable matters, and they are particularly fond of the petals and other parts of flowers, and of the juices of ripe fruit. In consequence of these predilections they are by no means regarded with favour by gardeners, whose choicest productions they often damage and



COMMON EARWIGS.

destroy; in fact, without adopting some means of keeping down the number of these little enemies of his labours, the gardener would often meet with very imperfect success. The lucifugous habits of the insects, which prompt them to hide themselves as soon as they are exposed to the light, suggest what is perhaps the most successful mode of dealing with them, namely, the placing in the immediate vicinity of the scene of their nocturnal depredations of convenient shelters, such as lobster's claws, reversed flower pots, or portions of reeds, into which the Earwigs creep to avoid the light, and from which they are easily dislodged and then destroyed. This same habit of creeping into holes has no doubt given origin to the name of Earwig, and the corresponding names applied to the insects in many languages. It is quite likely that they may often have sheltered themselves in the ears of persons sleeping in the open air, and such occurrences would easily suggest the idea that they went there for some felonious purpose. The old-fashioned belief that they could in this way penetrate to the brain has, of course, no foundation.

The female Earwig deposits her eggs under a stone in some cavity in the ground, often dug out

by her own labour. She afterwards watches over them with great solicitude, collecting them together if accidentally scattered, and moving them from place to place so as to keep them in favourable conditions as to moisture, &c., although there does not seem to be any foundation for the belief that she actually incubates them after the fashion of a bird. Even after the young are hatched the mother does not desert them, and the little creatures are described as taking refuge under the body of their mother, like chickens under a hen.

The species of Earwigs, which are generally of a yellowish, or lighter or darker brown colour, are tolerably numerous, and widely distributed over the surface of the earth. The tropical regions can hardly claim the same predominance over more temperate climates as regards either the number or the size of the species that we have seen in other families. The largest European species (*Forficula gigantea*), which is an inhabitant of some parts of England, measures about an inch in length of body, and these dimensions are not greatly surpassed by the exotic species, although some of the latter display much longer forceps than this insect can boast. The Common Earwig (*Forficula auricularia*) is found not only in Britain but all over Europe, and apparently throughout most of the Eastern Hemisphere, whether native or as an introduced species it is impossible to say. Another British species, the Little Earwig (*Labia minor*), is also of very wide distribution on the European continent, and is said to occur in North America. This insect frequents manure-heaps and hot-beds. It often flies in the afternoon in hot weather, like the little Brachelytrous Beetles with which it is found associated. The apterous species forming the genus *Chelidura*, in which the wings are altogether wanting and the tegmina also are rudimentary, are chiefly inhabitants of the mountainous parts of southern Europe.

SUB-ORDER II.—PSEUDONEUROPTERA.

In this second sub-order we group together a series of insects which present greater divergence of character than those referred to the Orthoptera Genuina—they are, in fact, the forms which used to be placed among the Neuroptera, but which have been separated from that group in consequence of the imperfect nature of their metamorphosis. As in the Neuroptera, however, the wings, when present, are of a membranous texture, and generally traversed by reticulated veins, and hence the name Pseudoneuroptera, though not a good one, is to some extent appropriate. In the structure of the mouth, in the very general presence of jointed styles or filaments at the extremity of the abdomen, as in the character of the metamorphosis, these insects certainly approach the true Orthoptera, and their first group is in many respects nearly allied to the Cockroaches.

TRIBE SOCIALIA.

This first tribe of the Pseudoneuroptera, as already stated in the table (p. 121), is distinguished by having four equal membranous wings, in which, however, the costal and subcostal veins running along the anterior margin are horny, and the space between them usually thickened and opaque, while the hinder, membranous part of the wing is traversed by finer veins, branching from the longitudinal veins that spring from the base of the wing, but rarely shows any cross-veins. These insects are further remarkable from their living in societies, composed of individuals of very different forms, all of which seem to take part in the business of the community, a condition of things which has given origin to the name of White Ants commonly applied to them. They form only a single family.

FAMILY VIII.—TERMITIDÆ, OR WHITE ANTS.

In this remarkable family of insects, the head projects freely in front of the prothorax, and bears a pair of beaded antennæ of from thirteen to twenty joints, two rounded eyes, and two ocelli. The three segments of the thorax are nearly equal in size, and very similar in form; the legs are simple, and terminate in four-jointed tarsi; and the abdomen, which has only a pair of very minute, two-jointed apical styles, is composed of nine distinct segments. The general characters of the wings, which are usually much longer than the body, have already been indicated; these organs are deciduous, falling off, or being pulled off by the insects themselves, after the performance of the so-called nuptial flight. The alliance to the Blattidæ is recognisable in various parts of the insects, but especially in the structure of the mouth, in which the labium very distinctly shows the Orthopterous character, and the galea, or outer lobe of the maxillæ, is a particularly large and important piece.

The character described of the family applies only to the mature males and females, but the societies of White Ants include other individuals which display at least two different sets of characters, but always present those which would seem to point to their being in an imperfect state of development, such as the absence of wings and ocelli. Of these two principal forms some have a large squarish head, with long projecting mandibles, and the prothorax larger than the other thoracic segments. These are called *Soldiers*. The others, called *Workers*, have a small rounded head with concealed mandibles, and, in fact, either are or resemble true larvæ. In both these forms the eyes are wanting. It would appear, however, that in the case of many species, at any rate, the constitution of the colony is more complex, as will be seen further on.

The Termitidæ are almost all inhabitants of the tropics, only a few comparatively small species being found in temperate climates. These species occur in southern Europe, one of which (*Termes lucifugus*) is abundant in some parts of France, and apparently indigenous; another (*T. flavicollis*) is a North African species which has been introduced into the south of France and Portugal; and the third (*T. flavipes*) appears to have been introduced from South America. In warm countries they form immense communities; and, as their appetites appear to be both indiscriminate and insatiable, they do an enormous amount of mischief in the in-



DIFFERENT FORMS OF WHITE ANTS (*Termes lucifugus*).

1, Workman; 2, Soldier; 3, Larva; 4, 'Supra-antennal Female'; 5, Nymph; 6, Male; 7, Female; 8, Gravid Female (all magnified).

habited localities infested by them. It would seem to be impossible to guard against their attacks, as they make their way underground, or in covered passages, until they reach the spot where their instinct tells them that they will find suitable food, when they make their way up into it, without any necessity of exposing themselves. In this way they will attack woodwork of all kinds, including articles of furniture, the substance of which they destroy, leaving untouched a thin outer shell, so that all the strength may be gone out of a wooden construction, while the appearance of solidity still remains. Even ships have occasionally been destroyed or rendered quite unserviceable by the ravages of these insects.

Their nests are made sometimes in the trunks or among the branches of trees, sometimes upon or in the ground. *Termes lucifugus*, already mentioned, is one of the species which take up their abode in galleries dug in woody material. They infest the trunks of pines and oaks, and will also

attack large posts and piles, in which way they have been exceedingly mischievous in some parts of France, especially in La Rochelle, where they attack the piles upon which a great part of the town is built. Many exotic species have similar habits, but they generally seem to affect certain species of trees. The nests made among the branches of trees, as also those attached to fences, and some ground nests, sometimes as big as a hogshead cask, are described by Mr. Hubbard, who observed them in Jamaica, as composed of a brown substance resembling *papier mâché*, probably composed of wood masticated by the insects, and mixed with a viscid saliva. Other ground-living species, such as the celebrated *Termes bellicosus* of South Africa, whose habits were described many years ago by Smeathman, build nests of clay, often of considerable size; thus the dwellings of the South African species just mentioned often attain a height of ten or twelve feet, and are of a conical form, with similarly conical turrets surrounding the main central edifice. These nests soon become covered with vegetation, and their strength is so great that men and large quadrupeds can stand upon them to obtain an elevated look-out point.

We cannot dwell further upon the structure of these remarkable dwellings, all parts of which are occupied by innumerable galleries and chambers, which usually have a single entrance, from which burrows and galleries are carried in all directions by the inmates. The habits and peculiarities of the latter must now engage our attention.

At a certain season, which differs for the different species, the winged males and females, which have undergone their last change a few weeks before, quit the nest and swarm into the air. After a short flight they descend again to the ground and lose their wings. The males sometimes commence the courtship of their partners during the flight, but more frequently not until after both have come down to the ground again, when the male closely follows the female as she walks about, often even seizing the extremity of her abdomen with his mandibles. It would appear, however, that these manœuvres are strictly of the nature of courtship, in which the male simply seeks to recommend himself to the notice of his intended consort. Unfortunately these sentimental proceedings are only too frequently cut short by the host of enemies—ants, birds, lizards, snakes, toads, and other animals—which flock greedily to the spot. It would seem, from the state of the internal reproductive organs at this time, especially in the males, that there is little likelihood of an impregnation of the female in the air during her short flight, such as takes place in the social Hymenoptera: and, in fact, it seems probable that nothing of the kind occurs until after the bride and her bridegroom have taken up their abode in some hospitable nest, and been adopted as the “king” and “queen” of the community. Their marriage, in fact, is for the remainder of their lives, which last for about a year from this time, and during this period the queen inhabits a large chamber usually placed



FEMALE TERMES, FROM THE AFRICAN COAST.

in the centre of the nest, where she dwells with her selected partner. Occasionally, according to Dr. Fritz Müller, one male may be found in attendance upon two females. After impregnation the ovaries of the queen

become exceedingly active, and eggs are developed in them in enormous numbers, so that the abdomen becomes immensely distended, and the chitinous dorsal and ventral plates are widely separated, forming mere patches upon an expanse of soft skin. In this condition the queen is, of course, quite helpless, and her sole business in life is to consume the food furnished to her and to produce eggs, of which she is said sometimes to lay as many as 80,000 in a day. These last are removed by the workers as fast as they are produced, and usually conveyed to the lower part of the nest. The food of the young larvae, according to Mr. Hubbard, consists of a prepared article stored up in the nest “in the form of very hard and tough rounded masses, evidently composed of comminuted wood.” These are scattered through the nests, often in considerable quantities, and

the larvæ attack them from beneath. The young larvæ, according to Mr. Bates, M. Lespès, Dr. Fritz Müller, and others, are all exactly alike, but before they have attained half the length of the full-grown workers, the appearance of the first rudiments of wings serves to distinguish the larvæ from which sexual individuals will originate from those of the soldiers and workers. It is only a little while before the last change of skin that the larvæ of the soldiers and workers can be distinguished. The soldiers are far less numerous than the workers, and their duty would seem to be the protection of the nest, as they make their appearance immediately when it is injured in any way.

M. Lespès, in investigating the history of the French *Termes lucifugus*, was the first to notice the presence in the nests of this species of two forms of so-called "nymphs" (a name here equivalent to pupæ), showing traces of wings in two different conditions. Some of these had long, broad wing-cases covering the anterior part of the abdomen (Fig. 5, p. 137); these give origin to winged male and female insects which swarm from the nests in May or early in June. The "nymphs of the second form" are less numerous, stouter, and heavier than the preceding (Fig. 4, p. 137), and have short rudiments of wings placed on the sides of the thorax. These were found to continue in the nest after the emergence of the winged insects produced from the first form, but their ultimate fate was only guessed at by M. Lespès. According to Dr. Fritz Müller, from whose valuable paper on the Termites we have here largely borrowed, these so-called nymphs, of which he recognizes two forms, are really perfect sexual insects, which he names "supplementary" males and females, regarding them as taking the place of the true "king" and "queen" in the event of such individuals failing to reach the nest. The following table given by Dr. Fritz Müller will make this complex business more intelligible.

1. Youngest larvæ.					
2. Larvæ of the asexual forms.			3. Larvæ of the sexual forms.		
4. Larvæ of the Soldiers.		5. Larvæ of the Workers.	8. Nymphs of the first form (Fig. 5).		9. Nymphs of the second form (Fig. 4).
6. Soldiers.		7. Workers.	10. Winged animals.		12. Supplementary males and females.
			11. King and Queen.		

In proof of the reproductive function of the supplementary females at any rate, Dr. Fritz Müller records his having found in the central mass of a White Ant's nest, instead of a royal chamber containing a queen and her consort, a series of irregular passages, in which he discovered thirty-one supplementary females crowded together here and there in groups of five or six, and accompanied by a single male, with large black eyes and the stumps of wings that had been fully developed. Abundance of eggs were found in the neighbourhood of this chamber. Dr. Müller witnessed the production of eggs by the supplementary females, and there was no queen in the nest, and hence, as our author says, instead of a royal palace in which a king was living in decent matrimony with a worthy consort, he had come upon a harem in which a Sultan was disporting himself in the midst of numerous concubines. Considering the immense number of winged individuals which are given off to almost certain destruction by every large community of Termites, and the existence of these wingless reproductive forms, Dr. Fritz Müller inquires what may be the purpose of such an apparent waste of the energies of the community, and finds it in the doctrine insisted upon with so much cogency by Mr. Darwin, of the advantage of cross-fertilisation to both plants and animals. The flight into the world of the winged individuals will bring the males and females emerging from different nests together, and thus facilitate inter-crossing, and he finds a confirmation of this view in the fact, already observed by Lespès, that the "nymphs of the second form" usually die off some little time after the swarming of the winged individuals, and the probable entrance into the nest of a new royal pair.

TRIBE CORRODENTIA.

The name of Corrodentia was given by Burneister to a group in which he included the insects next to be described, together with the White Ants, but later entomologists have separated the latter and retained the name for the former types. These insects have membranous wings with few

and simple veins, of which the hinder pair are not folded in repose; the front of the labium shows only two lobes; and the tarsi have two or three joints. The tribe includes two families.

FAMILY IX.—EMBIIDÆ.

This family consists of a small number of almost exclusively exotic species, which were originally regarded as forming a somewhat aberrant portion of the preceding family. Their fore and hind wings are narrow, and alike in form, size, and venation, the veins being parallel, or rather gently divergent, and simple, except that in some species there are cross veinlets at right angles between some of the veins towards the costal margin. In general form these insects have some resemblance to the Termites, but still more to the insects of the next family but one (*Perilideæ*), to which they would seem to be most nearly related. They have a large free head, with a pair of small eyes and a pair of beaded antennæ, but no ocelli; the prothorax is rather small and narrowed in front, and the other two segments larger and about equal in size; the legs are stout; and the abdomen is rather slender, of eight or nine segments, and terminated by a pair of two-jointed cerci. The maxillary palpi have five, and the labial, when present, three joints.

The species of this curious family are, as already stated, chiefly inhabitants of warm regions. They are found in Africa up to the shores of the Mediterranean, in Persia and India, and in South and Central America. None are yet recorded from Australia, but two species seem to occur in Southern Europe, namely, *Embia solieri* in the south of France, and a species, probably identical with the Egyptian *E. savignyi*, in Greece. Of their habits very little is known with certainty. The perfect insects of *Embia mauritanica* have been described as living in company on tall herbage, upon which they run with agility, but seem averse to make use of their wings. The larvæ are found under stones, where they reside in silken cases formed by themselves. M. Lucas says that they are carnivorous, and* that the silken webs serve to capture insects upon which the larvæ feed; but great doubt is thrown upon this statement by Mr. McLachlan, who has described a species (*Oligotoma michaeli*) the larvæ of which had apparently injured the roots of an Indian orchid in a hothouse near London, and were actually found to gnaw the roots when confined with them in a box.

FAMILY X.—PSOCIDÆ.

This is a family of small insects also with simply veined wings, but differing from the preceding in having the hind wings considerably smaller than the anterior pair. In some forms the wings are wanting. They have a rather large head, with the forehead inflated, and bearing a pair of long tapering antennæ, composed of from eight to about fifteen joints. The maxillary palpi are four-jointed, the labium bears no palpi, and the anterior wings show a large horny stigma on their costal margin.

The wings are fully developed in the great majority of the species, which also have three ocelli on the crown of the head, and tarsi composed of two joints. They are found upon the trunks of trees, old palings, walls, &c., in fact, in all those situations where lichens and mosses grow most luxuriantly, and it is upon these and other low forms of vegetation that they probably feed, although they may



CÆCILIX FENESTRATUS.

diversify their diet by consuming the still more minute animals that are to be met with in such places. They are active in their movements, and generally appear in the perfect state towards the end of the summer or in the early autumn. The females deposit their eggs in small groups upon the under surface of leaves, and cover them with a web of fine threads, which they are said to spin from some part of the mouth. The known species, which are not very numerous, are chiefly from the temperate parts of the Old World. Besides the winged species of *Psocus*, and one or two allied genera, the family includes some forms which are never known to acquire wings, and these are only too well known to collectors of insects. They live in books and among old damp papers, whence they are often known as Book Lice; they are also among the "mites" which do so much mischief to collections of insects and dried plants. They differ from the preceding in the absence of wings and ocelli, and in having the tarsi three-jointed. The best-known species is called *Atropos pulsatorius*, the specific name referring to an old belief that this feeble little creature was the "Death-watch."

TRIBE PLECOPTERA.

The insects of this tribe are specially distinguished from all the foregoing by the structure of the wings, which have the main longitudinal veins united by branches on the disc of the wings so as to form elongated cells, some of which are usually divided by cross-veins, and beyond which the apical part of the wing is traversed by about double the number of finer veins. The hind wings in nearly all are broader than the anterior pair, owing to the greater development of their hinder area; and in consequence of this they are folded in repose so as closely to wrap the abdomen. The name of the tribe alludes to this character. They form a single family.

FAMILY XI.—PERLIDÆ.

Besides the wing-characters above described, the Perlidæ show a rather elongated body, with a head of large or moderate size, bearing a pair of oval eyes, usually three ocelli, of which, however, the foremost is often very small or even quite rudimentary, and a pair of long, tapering, many-jointed antennæ. Of the parts of the mouth, the mandibles are generally weak and membranous, but sometimes horny and toothed; the maxillæ are rather small, but show distinctly the two lobes, and bear five-jointed palpi; and the labium is cleft in front and furnished with palpi of three joints. Although the wings are well developed, the three segments of the thorax are nearly of equal size; the legs are powerful, and terminated by three-jointed tarsi, of which the last joint is elongated and bears a large arolium between the claws. The abdomen is composed of ten segments, and has at its extremity a pair of jointed filaments, which are generally of considerable length, but sometimes short or quite rudimentary. In the males the wings are often less developed than in the females, a most unusual sexual difference, which applies sometimes to both pairs, sometimes only to the anterior.



PERLA MARGINATA AND ITS PUPA.

The species of this family, which are all of small or moderate size, are not very numerous, and chiefly inhabitants of the temperate regions of both hemispheres. Their larvæ, which closely resemble the perfect insects in general form, except that the prothorax is comparatively smaller, live in running water, and in the larger species are provided with branchial tufts on the under side of the thorax. They creep about upon and under stones, and on the stems of aquatic plants, and are carnivorous in their habits, preying upon smaller aquatic animals, and especially upon the larvæ of the Day Flies belonging to the next family. They also swim pretty freely, partly by means of their widened femora, and partly by undulating movements of the abdomen. The insects are believed to pass several years in their preparatory states, in the last (or pupal) stage of which they acquire the rudiments of wings packed away in cases on the sides of the thorax. When mature they creep up the stem of some plant until they get above the surface of the water, when they rest for a time, until the skin covering the head and thorax splits in the middle line, and the perfect insect creeps forth in a soft state, and with its wings still unexpanded. Even after the full development of the wings, the flight of the imago is slow and of short duration, and the males in many cases cannot fly at all. The perfect insects are generally found resting quietly on plants and other objects on the banks of the streams in which they have passed their earlier stages. The female extrudes her eggs so as to form a little mass adhering to the end of her abdomen, and this is afterwards dropped into the water during one of the short and sluggish flights performed by the parent.

The family is pretty well represented in Britain, where several species are well known to anglers, and supposed to be imitated in those curious productions known as "artificial flies." Thus a rather large brown species, about three-quarters of an inch long (*Perla bicaudata*), is known as the Stone Fly, and appears in April; a much smaller green species (*Chloroperla viridis*), found in May, rejoices in the name of the Yellow Sally, and is also known as the Willow Fly, the latter name being also given, according to Ronald, to a species of *Nemura*, probably *N. variegata*, in which the caudal bristles are rudimentary. The most remarkable circumstance connected with this family is the persistence of branchial tufts in the perfect insects of a small genus, described by the late Mr. Newman under the name of *Pteronarcys*, species of which have occurred in Canada and Siberia. The genus is distinguished by having all the wing-cells divided up by fine cross-veins; and branchial tufts to the number of eight pairs are appended to the stigmata of the thoracic segments, and of the first two segments of the abdomen.

TRIBE SUBULICORNIA.

The insects which we include under this tribe certainly present many points of divergence, and it is chiefly as a matter of convenience that we have retained the group as established by Latreille and adopted by Burmeister. The character referred to in its name is the form of the antennæ, which are short, awl-shaped, and composed of few joints. The wings are membranous, and generally much reticulated; the eyes are large, especially in the males; and the preparatory states, as in the Perlidæ, are passed in the water. The differences presented by these insects are very great, and enable us to distinguish two very well-marked families—the Ephemeridæ, or Day Flies, with very weak or even rudimentary mouths, and the hind wings much smaller than the anterior pair, and the Libellulidæ, or Dragon Flies, with powerful mouths, and wings approximately of equal size.

FAMILY XII.—EPHEMERIDÆ, OR DAY FLIES.

The Ephemeridæ are delicate, elongated, soft-bodied insects, with a moderate or small head, the surface of which, especially in the males, is chiefly occupied by the large compound eyes, between which are placed two or three ocelli. The antennæ, which spring from the forehead below the ocelli, are short and awl-shaped, consisting of two stoutish joints and a minutely-jointed bristle. The parts of the mouth are exceedingly feeble, and, in fact, often membranous in texture, the insect apparently taking no food in the perfect state. The segments of the thorax are very unequal in size, the mesothorax, as might be expected from the great development of the fore wings, being by far the largest; the fore wings are somewhat triangular, and the hinder ones rounded, but sometimes altogether wanting, and the principal veins in both pairs are more or less radiating, although branched, and united by numerous cross-veins, so that the wings are generally minutely reticulated. The legs are generally slender, and are terminated by tarsi composed of four or five joints; the anterior tibiae and tarsi are excessively elongated in the males. In the long slender abdomen eleven segments may be recognised, the last of which bears two or three very long, bristle-like jointed filaments, and the last but one in the males is furnished with peculiar sexual appendages.



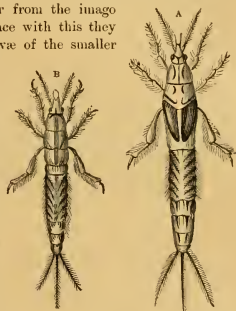
EPHEMERA VULGATA.

These insects, which seem to belong more especially to the temperate climates of the world, are remarkable for the great delicacy of their structure, and for the extreme shortness of their lives in the perfect state, which seems in general scarcely to exceed a day. Hence the name of *Ephemera* commonly applied to them. Their emergence, which generally takes place in the evening, is followed by a brief dancing existence on the part of the males, chiefly in the neighbourhood of the waters in which their preparatory stages have been passed, and as the insects are always produced in numbers, and the whole of the members of any given species within a district will make their appearance in the course of a few days, the swarms of Ephemeræ in particular localities are often enormous. On the banks of the canals and slow running rivers of the Netherlands and elsewhere in Europe the air for a few evenings is completely filled with these elegant creatures, and their number is so enormous

that in some places they are collected and used as manure. As their mouths are rudimentary they can take no food in the perfect state, and their sole business is the perpetuation of their kind. For this purpose the eggs are dropped into the water, being set free, in some instances at any rate, by the disruption of the abdomen of the mother.

The development of the larvæ always takes place in the water, and they frequent both streams and still water. The larvæ are not very like the perfect insects, and have a depressed body, long, bristle-shaped antennæ, long plumose caudal bristles, and a series of paired branchial leaflets appended to the sides of the abdominal segments. They differ further from the imago in the powerful development of their mouths, and in accordance with this they appear to be exceedingly predaceous in their habits. The larvæ of the smaller species usually live freely in the water, but those of many of the larger ones burrow most ingeniously into the banks of the stream or pond that they inhabit, making a sort of U-shaped double gallery with two openings to the water, which flows into them, so that the inmate can go in and out without the inconvenience of turning in his abode. If the insects of this family have but a short existence in the perfect state, they make up for this by considerable longevity in their earlier stages, which appear usually to occupy two or three years, during which the changes of skin are very numerous. Sir John Lubbock found that a small two-winged species (*Cloëon dimidiatum*) moulted twenty times in the course of its aquatic existence, and that each moult was associated with greater or less structural changes, until the final condition in which the wings have attained considerable development within their cases. The stage succeeding this is, however, the most extraordinary in the life of the insect. The creature that emerges from the so-called "nymph" is apparently an imago, and is able to use its wings sufficiently to fly to some resting-place, but it is not yet quite nature; all its parts are covered by an exceedingly delicate pilose pellicle, which completely masks the true colour of the perfect insect, and has still to be stripped off before the imago appears. This "subimago," or "pseudimago," as it has been called, attaches itself to various objects on the shore, such as the trunks of trees, palings, the stems and leaves of grasses and other plants, and even the clothes of passers-by; then, after a longer or shorter interval, the outer pellicle is ruptured and the insect comes forth, with brighter wings and much longer caudal bristles, and flies away, leaving the delicate skin still clinging by its claws to the chosen resting-place.

Of British species of this group the best known are the May Flies (*Ephemera vulgata*), of which the subimago is called the Green Drake and the imago the Grey Drake by anglers. These are large species. The little two-winged *Cloëon diptera* and several species of *Bæëtis* in which, as in *Cloëon*, there are only two caudal bristles, are also common.



LARVA (A) AND PUPA (B) OF *EPHEMERA VULGATA*.

FAMILY XIII.—LIBELLULIDÆ, OR DRAGON FLIES.

In this second family of the Subulicornia, the hind wings, as already stated, are approximately of the same size as the anterior pair, a character which at once serves to distinguish them from the Ephemeriidæ. The insects have a large broad head very freely attached to the thorax, and large, convex, prominent eyes, which often meet upon the crown of the head, and have the facets of the upper part larger than those of the lower. Between the eyes are three ocelli, two of which always rest upon the vertex, and the third sometimes upon a bulbous projection of the front of the head, above which originate the short, awl-shaped antennæ, consisting of six or seven joints, of which the first two or three are stouter than the rest. The large labrum conceals the other organs of the mouth, which consist of a pair of strong, horny, toothed mandibles, and a pair of maxillæ, showing a single horny lobe, and a palpus of one joint, unless the palpus be really wanting, and the organ usually so called represent the galea. The mouth is closed below by a broad labium, which is of peculiar construction, the outer lobes being amalgamated with the two-jointed palpi, and the inner lobes either

separated or united into a single piece. The structure of the thorax is also peculiar. The prothorax is small and ring-like, and the meso- and meta-thorax are of large size, and placed almost horizontally one above the other, so that the true back to which the wings are attached is quite behind, and the breast, with the legs, thrown forward towards the head. The wings are closely reticulated, and the legs of moderate length and strength, and terminated by three-jointed tarsi. The abdomen is elongated, sometimes very long and slender, and is composed of eleven segments, of which the last but one bears a pair of unjointed claw-like or leaf-like appendages.

These insects, which are for the most part of moderate or large size, constitute a very numerous group, some fourteen hundred species having been described from all parts of the world. They are numerous and abundant in temperate climates, but become still more so within the tropics, where also



LIBELLULA DEPRESSA.

the finest species are met with. Nevertheless, the warmer regions have not so much advantage over extra-tropical countries in the case of this group as of some others; some of the European and British species may vie in size and colouring with all but a few of their exotic relatives.

Their habits are everywhere much the same. Like the Ephemeridæ they are generally found in the vicinity of water, in which element their preparatory stages are passed, but quite unlike those abstemious creatures, they are exceedingly voracious in their habits, continually hawking about upon their long

and powerful wings in pursuit of their prey, which consists entirely of weaker insects captured in the air. Thanks to a particularly powerful arrangement of muscles and tendon-like pieces contained in the large thoracic segments which bear the wings, those organs are capable of almost incessant action, and the Dragon Flies may be seen throughout a summer's day continually sweeping about over the surface of some pond or stream, or poising themselves motionless in the air from time to time by excessively rapid vibrations of the wings. They rest at night, and sometimes by day, especially in dull, cloudy weather, upon the twigs of trees and bushes, and the stalks and leaves of grasses and other plants, and it is singular to observe how easily the insect when thus resting escapes observation, notwithstanding its considerable size and often striking coloration. Their courtship is one of the most singular points in their history. The male seizes the female by the neck with the claspers appended to the last abdominal segment but one, and thus united the pair may often be seen in flight. After a time the female curves the end of her abdomen forward until it comes in contact with the second abdominal segment of the male, which is singularly inflated and cleft, and contains an organ by means of which the fertilising male elements are introduced into the proper position for fecundating the eggs; and what renders this arrangement still more singular is, that in the male the ducts leading from the organs secreting the fertilising fluid open near the end of the abdomen in the ninth segment, so that he must, before going in search of his mate, purposely charge the reservoir in the second segment of his abdomen. After the completion of the process, the pair usually separate, but in some instances the male continues to clasp the neck of the female, so as to assist her in flying over the surface of the water in order to deposit her eggs suitably.

In their general form the Libellulidæ present very considerable differences, and in accordance with these we may distinguish three principal groups. In a very great number the head is short and transverse, forming a sort of cylindrical piece, on the two ends of which the eyes are situated, separated by a wide crown on which the ocelli are placed; the abdomen is cylindrical and very slender; and the wings, which are of equal size, are closed together over the back of the abdomen in repose. These, forming the sub-family AGRIONIDÆ, are the most elegant of all the species, and it is no doubt in allusion to the graceful slenderness of their forms, and to the mode in which they are as it were draped in gauze when their wings are closed, that French collectors have bestowed upon the Dragon Flies in general the fanciful name of *Demoiselles*. Several species are exceedingly

abundant in Britain. *Agrion puella* in which the abdomen of the male is banded with azure blue, while that of the female is almost entirely brassy black, is an insect about an inch and a quarter long that occurs almost everywhere; and the beautiful *Calopteryx virgo*, of which the male is steel-blue with a large brown patch with steel-blue lustre on each wing, and the female rather greenish with brownish wings, is to be met with frequently about running waters. Some American species have the abdomen of inordinate length, extending far beyond the closed wings. These form the genera *Megaloprepes* and *Mecistogaster*, species of which attain the length of four or five inches.

In a second group, that of the *ÆSCHNIDÆ*, the abdomen is still cylindrical, but stouter in proportion than in the *Agriionides*. The head also is large and nearly hemispherical in form, and the eyes are enormous, usually covering the whole upper and lateral surfaces, and meeting on the crown in the middle line. The wings are always extended at the sides of the body. These are large and strong insects, possessing a wonderful power of flight, and several species are common in Europe and Britain. The Great Dragon Fly (*Æschna grandis*) is one of these. It is nearly three inches long, and is of a light rusty brown colour, with a few paler markings. Another is *Gomphus vulgatissimus*, a black insect nearly two inches long, with yellow bands on the thorax and a line of the same colour along the back of the abdomen. Some of the tropical species attain a considerably larger size.

Finally, in the true *LIBELLULIDES* we find the head, eyes, and wings showing the same general characters as in the last group, but the abdomen is either broad and more or less flattened or comparatively slender, and then triangular in section. In some forms the abdomen shows an approach to the type of the *Æschnides*, but then recourse may be had to a small character presented by the wings, which have a marked triangular space a little way from the base, and this is alike in both pairs of wings in the latter, but different in the *Libellulides*. The best-known English species of this group is the *Libellula depressa*, vulgarly known as the Horse Stinger, an insect nearly two inches long, with a rather broad depressed abdomen, which is yellowish-brown with yellow spots on the sides in the female, and coated with a beautiful violet-blue powder in the male. It may be seen almost everywhere hawking about over rivers and ponds.

The larvæ of these different forms, although not very closely resembling their parents, nevertheless differ from each other in general form, somewhat after the same fashion as the perfect insects, but all agree in one character, namely, that of being among the most predaceous of the insect inhabitants of the water. The apparatus by which they capture their prey is of the same general nature in all, and consists of a peculiar modification of the labium, which has been called the "mask." In repose the chin-piece is folded back towards the breast, and to its extremity the broad labium is attached by a hinge-joint, and the anterior margin of this bears a pair of forceps-like organs, representing the outer lobes of the labium united with the palpi, and articulated so as to close towards the middle of the labium. Sometimes these terminal pieces are so large as to cover a great part of the face when the labium is retracted; in all cases the labium with its appendages completely closes the



AGRION PUELLA.



NYMPH OF LIBELLULA, AND THE PERFECT INSECT EMERGING.

mouth. In seizing a prey it is darted out towards the victim, which is firmly grasped by the apical forceps, and then easily conveyed within reach of the other organs of the mouth.

Besides the difference of form, these larvæ also present important differences in their respiratory apparatus. In the Agrionides the larvæ are always provided with external branchial organs appended to the extremity of the abdomen, sometimes alone, sometimes in conjunction with an internal breathing apparatus similar to that prevailing in the other two groups, which consists of a peculiar arrangement and ramification of tracheæ in the walls of the rectum or terminal portion of the intestine. The water is drawn into and expelled from this by the action of special muscles, and the expulsion is so forcible that the creatures are slowly moved through the water by its recoil. The insects are active and voracious throughout their preparatory stages, in the last of which they show large wing-cases behind the thorax. When full grown they crawl up the stems of some aquatic plant into the open air, and after resting there for a longer or shorter time, the skin splits along the thoracic region, and the perfect insect by degrees struggles out of its investment. The wings, at first, have not attained their full development, but this is soon reached, and the Dragon Fly starts off to continue in the air the same scene of rapine that has characterised its subaqueous existence.

SUB-ORDER III.—PHYSOPODA.

The Physopoda are a curious group of insects, the true position of which has been always doubtful. Some writers place them with the Orthoptera, others with the Rhynchota, and others again in a separate order, side by side with one or other of those just mentioned. We have preferred here to follow Burmeister and those entomologists who have adopted his view of the matter.

These insects have a narrow flattened body, and two pairs of narrow wings, which show few or no veins, but have their margins fringed with longish hairs, whence the name of Thysanoptera (or "fringed wings") was applied to the group by the late Mr. Haliday. In repose these wings lie flat over one another upon the back of the abdomen, leaving the margins of the latter exposed. The head is of a somewhat cylindrical form, and bears a pair of large eyes, a pair of



LARVA (A) AND IMAGO (B) OF THIRPS CEREALIMUM.

antennæ consisting of eight or nine joints, and three ocelli placed between the eyes. The wings and ocelli are deficient in some species. The mouth is bent back towards the breast, and pointed, so as to remind one of the character of the rostrum in the Homoptera, and still more in the *Notonecta*, but its structure is very different.

Thus the mouth is closed in front by a pointed labrum, behind which is a pair of bristle-like mandibles more or less dilated at the base. Within these again are found two simple maxillæ, bearing palpi of two or three joints; and the whole apparatus is completed by a membranous labium, pointed in front, and furnished with short two-jointed palpi. The legs are of moderate length, or short, and have tarsi of two joints, the second of which bears no claws, but terminates in a bladder-like disc, by means of which the insects adhere to the objects upon which they walk. Hence arises the name of Physopoda, and the action of these little suckers causes the insects to produce a very uncomfortable tickling sensation when they run upon the skin of people's faces.

The insects of this group are all small. The ordinary run of species are about one-twelfth of an inch long, many less, and those of an eighth of an inch may be looked upon as large. From this point of view the species of *Idolothrips*, which inhabit Australia, are gigantic, measuring from a quarter to a third of an inch in length. The Physopoda are no doubt abundant in all parts of the world, but comparatively few extra-European species have been recorded. In Europe, however, they are numerous, and may be found throughout the summer upon the leaves and flowers of plants, especially the latter, where they often look like so many black streaks scattered over the bright petals. Many of them, however, are not black, and some seem to copy the colours of their favourite flowers. The larvæ, in all stages, are found in the same situations as the perfect insects, which they

closely resemble in general form and structure, differing chiefly (besides the want of wings in those of the winged species) in greater softness of the skin, in the shortness of the antennæ, and in having agglomerated instead of compound eyes. In the last, or nymph stage, the wings are usually seen in their cases, but the antennæ are turned back upon the head. There is a filmy integument about the joints of the limbs, and the insect is more sluggish than in the larva or perfect state.

Although the mouth, as we have seen, is constructed upon a mandibulate type, the insects appear to use it for suctorial purposes, although the precise mechanism by which it acts does not seem to have been made out. There are two principal groups or families of these insects, in one of which, the TUBULIFERA, the last segment of the abdomen in both sexes forms a little tube; while in the other, the TEREBRANTIA, the females are provided with a regular ovipositor composed of four minute valves concealed in a groove of the last two ventral segments. In the former the antennæ are eight-jointed; the latter usually have nine-jointed antennæ, and they possess the power of jumping by the agency of the abdomen. These insects are generally known to gardeners by the name of the Thrip or Thrips, the latter being the name of the most typical genus. Some of them occasionally prove injurious to cultivated plants. This is especially the case with the Corn Thrips (*Thrips cerealeum*), which generally attacks the ears of corn, and when numerous may be mischievous.

SUB-ORDER IV.—MALLOPHAGA.

These insects may be denominated "mandibulate lice," that is to say, both in appearance and general habits they somewhat resemble the true Lice, with which they were formerly arranged, but differ in the possession of biting mouths, and in the diet to which such a structure adapts them. They are small flat insects, with the upper surface more or less horny in its texture; the head is broad and horizontal; the thorax narrow and destitute of all traces of wings; the abdomen usually broad and of nine or ten segments; and the legs short and stout, with tarsi of two joints furnished with one or two claws. The eyes are small and usually simple; the antennæ consist of from three to five joints; and the mouth, which is situated beneath the head, contains a pair of short hooked mandibles, a pair of small maxillæ with or without palpi, and a labium with palpi of two joints.

A great number of these curious little insects have been recorded, and they inhabit all parts of the world, in fact it would seem as if there were few birds at any rate to which no parasite of this group is attached. They live among the hairs of the Mammalia and the feathers of birds, each species of parasite being usually attached particularly to some species or small group of species of these warm-blooded Vertebrates; but unlike the true Lice they do not feed upon the blood of their hosts, but upon the finer hairs and downy feathers. Frequently they occur in considerable numbers, and may then perhaps, to some extent, be injurious.

Here again two principal families may be distinguished. The PHILOPTERIDÆ have thread-shaped antennæ of three or five joints, and no maxillary palpi. The species with five-jointed antennæ (*Philopterus*, *Nirmus*, *Docophorus*, &c.) infest birds; and those with the antennæ of three joints (*Trichodectes*, &c.) are found upon mammals of various groups. In the second family (LITHIIDÆ) the antennæ are clubbed and composed of four joints, and the maxillary palpi are present. Species with distinct labial palpi, and two claws on each tarsus (*Liothium*, and allied genera), live upon birds; and those with no labial palpi, and with only one claw on each tarsus, on mammals. The common fowl, ducks and geese, game-birds of all kinds, and pigeons are very commonly infested by these parasites, as are also the dog and cat, the sheep and the guinea-pig.



PHILOPTERUS SELCIFERUS.

ORDER THYSANURA.

We have now reached the last order referred to the class of true insects, and it is a group of no small interest from a philosophical point of view. The forms composing it are reckoned to present the nearest resemblance to the theoretical progenitors of the Insecta—in fact, Sir John Lubbock hints that they might well be regarded, not as insects at all, but rather as the surviving

and perhaps modified representatives of a group formed by the ancestors of the whole multitude of insect types which we have here attempted to pass in review.

The Thysanura have been considered by different entomologists to form either a distinct order or a section of the Orthoptera, while some writers have even thought that they might rather be united with the next class. Considering this diversity of opinion, and the real peculiarities of organisation from which it springs, it seems best to treat these little creatures as actual members of the class of insects, with which they most nearly agree in structure, but to give them prominence by ranking them as a distinct order. At the same time, while an undoubted close relationship runs through all the members of the order, there is sufficient difference in the groups of which it is composed to render it difficult to formulate a set of characters which shall apply pretty equally to the whole.

One primary character is to be found in the entire absence of wings, and of any metamorphosis; and a second, in the feebleness of the organs of the mouth, which are also generally concealed within the cavity of the head. The eyes, when present, are almost invariably ocelli or simple eyes, either placed singly or aggregated in groups on the sides of the head; true compound eyes occur only in one genus. The body is generally rather soft in texture, and has its surface clothed with peculiar hairs and scales somewhat resembling those of the Lepidoptera, but of course much smaller, some of them being among the most delicate objects for the microscope. The lower surface of the abdomen is usually furnished with appendages, as also the apex of that region in some species, and these, which vary considerably in structure, serve in the majority as saltatorial organs. The members of this order generally frequent obscure places, and some of them show a preference for moist localities, while others delight in dryness and warmth. Their food consists of decaying vegetable matter.

Sir John Lubbock divides them into two orders, the THYSANURA and the COLLEMBOLA. At the same time, he shows that some members of the former group are very nearly related to those of the second, and therefore we may take the two groups, which really agree precisely with the families generally accepted by previous writers, and regard them as forming two great tribes of the same order.

TRIBE I.—THYSANURA GENUINA, OR BRISTLE-TAILS.

This group is distinguished by having long antennæ composed of many joints, tarsi of from two to four joints, and more or less exposed mandibles and maxillæ. The maxillary palpi are often long, and composed of five or seven joints, sometimes shorter, and only two-jointed; the labium is more or less cleft in front, and bears four-jointed palpi; the prothorax is large; and the under surface of the abdominal segments, or of some of them, bears pairs of appendages (rods or tufts), besides, in general, two or three long, jointed, caudal bristles. The body in these insects is almost always clothed with metallic scales, which closely cover the whole surface, and give the creature a beautiful silvery appearance; but, unfortunately, these scales are rubbed off by the lightest touch, and it is very difficult to capture one of these insects without sadly spoiling its beauty. In some respects, especially in the conformation of the organs of the mouth, the more typical members of this tribe, forming the family LEPISMIDÆ, approach most nearly to the Orthoptera, and among the latter the alliance would seem to be closest with the Blattidæ.



LEPISMA SACCHARINA.

Of this family a good many species are known, chiefly from different parts of Europe and the neighbouring countries, the largest of them being rather more than half an inch long. *Lepisma saccharina*, a silvery creature like a little fish, is not uncommon in Britain, living in decaying wood, and also frequenting houses, where it commonly takes up its abode in the sash-frames of the windows. It runs rapidly, but does not leap. In the genus *Machilis*, two species of which inhabit Britain, the ventral segments are nearly all furnished with paired appendages, and those of the ninth segment are converted into a springing fork homologous with that characteristic of the next tribe. One British species (*M. polygota*), which is brown with a metallic lustre, is found in woods and dry places; the other (*M. maritima*), a mottled brown species, occurs under stones on rocky shores. These insects are about half an inch long. They have com-

pound eyes. *Camptodon staphylinus*, a small elongated species about a sixth of an inch long, with two caudal bristles, is common in loose, damp ground both in England and on the continent. It has the palpi short, and all the parts of the mouth minute, and is regarded by Sir John Lubbock as a sort of central type, from which many others have been derived. It is the type of the family CAMPTODEIDÆ. Both this and the family JAPYGIIDÆ show a strong affinity to the second tribe (the Collembola). *Japyx solifugus*, a white species less than half an inch long, is found under stones in different parts of the south of Europe. It is much elongated, and the abdomen terminates in a pair of little horny forceps, closely resembling those of the Earwigs. Another species (*Japyx gigas*), from Cyprus, is the giant of the Thysanura, sometimes measuring more than an inch long.

TRIBE II.—COLLEMBOLA, OR SPRING-TAILS.

The Collembola, which correspond to the family Poduridæ of most authors, have the antennæ comparatively short, and composed only of from four to six joints; the organs of the mouth concealed within the buccal cavity, and destitute of palpi, except a pair of rudimentary organs, which Sir John Lubbock identifies with the maxillary palpi in certain species; the prothorax small; the tarsi of a single joint, and the abdominal appendages represented by a single pair springing from a segment near the apex (the last but one, or the last but two), united at the base to form a springing fork, and bent forward in repose, so as to reach nearly or quite to the head. By the action of this fork, the arms of which are frequently jointed, and furnished with adhesive hairs, the insects thus endowed are enabled to spring to a considerable height in the air, the process being precisely analogous to that by which the common toy frogs are made to jump. In form these insects are sometimes irregularly globose, but more commonly rather elongated, although never presenting the rather elegant, fish-like shape of many of the preceding tribe. Their surface is covered with hairs or scales, or with a mixture of both. The tarsi are terminated by a single curiously-cleft claw. The abdomen consists of six segments, on the ventral surface of the first of which there is a very peculiar organ. This consists of a cleft tubercle, or a short tube divided at the free end into two lobes, from which the animal can protrude two long, delicate tubes, covered with minute glands, by means of which, and of a viscous fluid produced by these curious organs, their fortunate possessors are enabled to adhere with facility to smooth vertical objects upon which they may be walking. According to some writers, there are four pairs of stigmata upon the first four segments, leading into a regular tracheal system; but the existence of the latter is by no means demonstrated in all the forms of this tribe. Sir John Lubbock seems to have detected tracheæ only in one genus examined by him (*Sminthurus*), and he declares that the stigmata leading into these tracheæ are situated upon the under side of the head. This is a most unusual situation for the tracheal openings.

The Collembola are all small insects, a length of a quarter of an inch being considerably above the average. They are found commonly in loose earth, under decaying leaves in woods, in moss, under the bark of dead trees, and in rotten stumps. They always prefer damp situations. Cold seems to have but little effect upon them; they will recover their activity after being frozen. One species (*Desoria glacialis*) is found enjoying itself upon the Swiss glaciers; and another (*Degeeria nivalis*) occurs upon the surface of snow in many parts of Europe. Some also may be met with hopping about upon the surface of standing water; *Podura aquatica*, a minute blue-black species, is common in such situations in England. *Orchesella cincta*, one of the finest and handsomest species, a quarter of an inch long, distinguished by having a black band on the third segment of the abdomen, is found commonly under dead leaves, and in moss; *Toxocerus plumbeus*, a rather smaller species, is found under logs of wood.



ORCHESELLA, CINCTA.

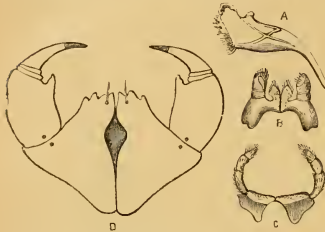
W. S. DALLAS.

CLASS MYRIOPODA.

THE CENTIPEDES AND MILLEPEDES.

Definition of the Class—External Structure—Internal Structure—Reproduction—General Habits—Fossil Forms—Classification—Order CHILOPODA—Structure—Distribution—Habits—Family SCUTIGERIDÆ—Family SCOLOPENDRIDÆ—Centipedes—*Lithobius forficatus*—*Scolopendra ringulata*—*Geophilus*—Phosphorescence—Order CHILOGNATHA—Family JULIDÆ—Millepedes—*Julus sabulosus*—Family POLYDESMIDÆ—Family SIPHONIZANTIA—Family GLOMERIDÆ—Order PAUROPODA—*Pauropus huxleyi*—Order ONYCHOPHORA—*Peripatus*.

THE Myriopoda, commonly known as Centipedes and Millepedes, form one of the most interesting groups of the whole animal kingdom. In the general structure of the body, which in most of them consists of a considerable number of similar segments, they present a close resemblance to the highest forms of the Vermes, the Annelida, and indeed one type that we must refer to the class (*Peripatus*) would seem to constitute a complete transition between the two classes; whilst, on the other hand, in the organisation of the mouth, and the presence of only a single pair of true jointed antennæ, we find



PARTS OF MOUTH OF A SCOLOPENDRA.

A. Mandible; B. united maxillæ and labium; C. first pair of legs; D. second pair of legs.

a transition equally complete towards the true Insecta. Some zoologists have dwelt with perhaps undue force upon the analogy between the Myriopoda and the larvæ of insects with a perfect metamorphosis; but too much importance can hardly be ascribed to the fact that the youngest larvæ of some of the Myriopods are furnished only with three pairs of legs, and in other respects much resemble the young of insects with an imperfect metamorphosis, and above all the Collembolous group of the Thysanura.

The Myriopoda may be defined as Arthropods with a distinct head, and most of the other segments almost precisely similar to one another, with a single pair of antennæ, and nearly always with simple eyes, with no distinct thorax, and with-

out wings, but with limbs attached to all, or nearly all, the segments of the body. The respiration, as in the insects, is effected by means of tracheæ.

The head, as already stated, is a distinct part, and agrees in general with that of the Insecta, bearing a single pair of antennæ, which are almost invariably simple, jointed organs. The organs of vision generally consist of simple eyes (ocelli), which, however, are often closely grouped together on the sides of the head. In one family true compound eyes are present. As in the Insecta also, we find three pairs of jaws represented in the mouth, the mandibles being distinct, while the maxillæ and labium are united to form a sort of lower lip, and are thus deprived of all lateral motion. No palpi are recognisable upon any of these parts. In one of the orders into which the class is divided the limbs of the first two body-segments take part in the formation of the mouth. The segments of the body are nearly alike throughout; they are generally horny, and furnished with a pair of jointed limbs. The number of segments varies greatly in the different groups, and even in the genera, the lowest being ten, the highest about one hundred and sixty. In the Centipedes (Chilopoda) we find a slight difference in the character of the first two segments, of which the dorsal part is suppressed or concealed by the head, while the limbs, as already indicated, take part in the formation of the mouth. In the remaining groups the segments are uniform in their development, except that they may become broader towards the middle of the body. The legs, which are usually short, are attached sometimes at the sides of the ventral plates, sometimes close to the middle line of the lower surface of the body. In the latter case each segment bears two pairs of legs, and it becomes a question whether we should not regard the apparent segments as really formed by an amalgamation of two primitive segments. These limbs consist of six or seven joints, of which the last, except in one singular worm-like type, bears a single claw. If we name these joints in accordance with the nomenclature of the parts of the

limbs in insects, the first three will be the coxa, trochanter, and femur, the fourth and fifth will represent the tibia, as in the Spiders, and the sixth, or sixth and seventh, which usually differ more or less in form from the preceding ones, will form the tarsus.

In their internal structure the Myriopoda closely agree with the insect type. The intestinal canal shows the same parts as in the Insecta, but usually drawn out to a greater length, to correspond with the general elongation of the body, through which it passes nearly in a straight line. A narrow œsophagus gradually expands into a stomach, which, however, is only a widened part of the tube, and this is followed by a straight intestine running to the extremity of the body. As appendages to the intestinal canal, we find from one to three pairs of salivary glands, and one or two pairs of Malpighian vessels, the former opening into the cavity of the mouth, the latter into the intestine not far from its termination. The nervous system of these animals consists of a ventral chain, which shows the same uniformity of general construction that is observed in the larvæ of insects with a perfect metamorphosis, the ganglia corresponding in number with the body-segments, except that in most cases the commissures uniting the successive ganglia are very short, often so short that the central system forms a cord rather than a chain. The ganglia of the first three segments following the head are regularly united into a continuous mass. In the head there is the same nervous ring embracing the œsophagus as in insects, and from it are given off nerves to the antennæ and eyes, the latter of considerable thickness when the organs of vision are greatly developed. In the worm-like genus *Peripatus*, which is placed with the Myriopoda, but in all probability represents a survival of a type intermediate between the Annelida and the Myriopoda, the ventral nervous cords are widely separated.

As in the Insecta, the central organ of circulation, the so-called heart, is a dorsal vessel, divided into successive chambers agreeing in number with the segments of which the body is composed, and each chamber is attached to the walls of its segment by a pair of triangular muscles. The blood penetrates these chambers through a pair of lateral slits, and, according to Newport, a portion of it is again driven out through a small artery situated in front of the slit, but the greater part is driven forward and discharged into the cavity of the head through an aorta which divides into three branches. Respiration, as already stated, is effected, as in the Insecta, by the agency of tracheæ, which open by regular stigmata, usually placed either towards the middle of the ventral surface close to the articulations of the legs, or in the membrane uniting the dorsal and ventral plates of the segments. In one type, however, the stigmata form a single row of openings in the middle of the upper surface of the body, one being placed close to the hinder margin of each of the dorsal plates; and in *Peripatus* the tracheæ are short and open irregularly in all parts of the skin of the animal.

The reproduction of the Myriopoda is always by eggs, and the young animals, on quitting the egg, although allowing the general characters of their parents to be recognised, present certain rather important differences from them. Thus the numbers of the body-segments, of the joints in the antennæ and of the ocelli are always less, and the young Myriopod, when first hatched, has only three pairs of legs attached to the three segments immediately behind the head. With each change of skin undergone by the larva the number of each of these parts increases until the adult construction is attained; new segments are formed in the body between those already in existence, new joints are added to the antennæ in the same way, new ocelli make their appearance on the sides of the head, and the number of leg-bearing segments steadily increases.

In their habits the Myriopoda are generally darkling creatures, living a concealed life in the ground, under stones, in crevices of rocks and buildings, and under the loosened bark of trees. They are distributed in all parts of the world, but the largest and finest species are all inhabitants of hot climates, where some of them attain gigantic dimensions. The food of some of them is of a vegetable nature, although it would appear that even these will not disdain animal food on occasions; others confine themselves to the latter diet, and are most formidable predaceous creatures.

The oldest known members of the class, in fact almost the only ones known to occur in the fossil state, belong to the vegetarian forms above mentioned (the Chilognatha). Remains of several species apparently belonging to this order, although showing very peculiar characters, have been discovered in the Carboniferous formation of North America, some of them even contained in the hollow trunks of trees of the genus *Sigillaria*. One or two allied forms have also been detected in the Coal Measures of Britain. The Permian rocks of Germany, immediately succeeding, or, perhaps, concluding the

Carboniferous period, have also furnished a peculiar species. A species referred to *Geophilus*, and therefore to the carnivorous order Chilopoda, occurs in the lithographic slates of Solenhofen. A few Tertiary fossil species are known, and many occur enclosed in amber.



DEVELOPMENT OF JULUS TERRESTRIS. (After Newport.)

1, Embryo at rupture of egg; 2, at end of first day; 3, on third day; 4, on ninth day; 5, newly-hatched *Julus* on seventeenth day; 6, on nineteenth day; 7, on twentieth day; 8, on twenty-sixth day.

We divide the Myriopoda, including the abnormal type *Peripatus*, into four orders, as follows:—

* *Breathing Apertures regular Stigmata.*

1. CHILOPODA (Centipedes), with the antennæ simple, the body depressed, the dorsal and ventral plates horny, united by a membrane; the legs inserted in single pairs at the sides of the segments, with the exception of the first two pairs, which are converted into mouth organs.

2. CHILOGNATHA (Millepedes), with the antennæ simple, the body usually convex, or even cylindrical, the dorsal plates bent round so as to meet the narrow ventral plates nearly in the middle line of the body, each segment, after the fifth or sixth, with two pairs of legs.

3. PAUROPODA, with branched antennæ.

† *Breathing Apertures scattered.*

4. ONYCHOPHORA, worm-like, with a soft skin, simple antennæ, and legs terminated by two claws.

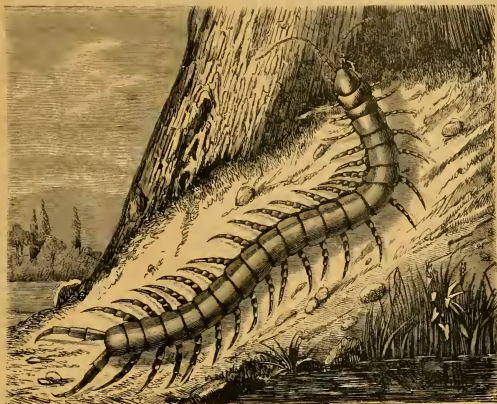
ORDER I.—CHILOPODA.

The leading characteristic of the Myriopods of this order has been already indicated (p. 150). It consists in the conversion of the first two pairs of legs into auxiliary organs of the mouth. In general the dorsal part of the first two segments is reduced to a rudimentary condition, and their limbs are always curiously modified. Behind the lower lip, of which the middle part is formed by the united halves of the labium, while the lateral portions consist of the maxillæ, the whole united into a single plate, the limbs of the first body-segment make their appearance, the coxal portions being united in the middle line so as to represent a sort of second labium, from which springs a pair of three-jointed organs like palpi (the homologues of the first pair of legs). These parts are feebly developed, but the limbs of the second segment attain a large size and a very remarkable structure. Their basal parts are expanded into two broad, irregularly triangular plates, united in the middle, each of which bears a sickle-shaped organ composed of four joints, representing the true limb. The basal joint of these hook-like parts is of large size, and is followed by two broad but very short joints, and these again by a long, powerful,

curved, tapering joint, terminated by a sharp, perforated claw, through which the poison secreted by a gland can be poured into the wounds inflicted by the point. The whole of this apparatus lies flat upon the under surface of the head, usually closing the mouth from beneath entirely.

The segments behind the head, which vary in number between sixteen and over a hundred, are formed by separate horny dorsal and ventral plates, joined at the sides by a membranous part in which the stigmata are usually situated. Each of these plates more or less overlies the one behind it, and in some forms, the alternate dorsal plates are so large as to cover those between them, causing the number of segments to appear only half what it really is. In these cases, however, the ventral plates indicate the true number of segments.

The rudimentary condition of the dorsal plates of the first or first and second segments has already been mentioned; and these, and the third segment, are to be regarded as constituting a thoracic region homologous with that of insects. Each segment of the body, from the third onwards, bears a pair of jointed legs, which spring from the borders of the ventral plates and stand out from the sides of the body. They are usually of moderate length, but sometimes very long. The legs attached to the last segment are



SCOLOPENDRA CINGULATA.

generally much longer and stronger than the rest, and differ from them also in being directed backwards nearly in a line with the body. The antennæ are long, composed of many joints, and tapering in form. The stigmata are usually placed on the alternate segments, and lead into a system of tracheæ closely resembling the type seen in insects. The organs of reproduction open at the posterior extremity of the body, and the impregnation of the females is said to be effected by the agency of spermatophores, which the males attach to irregular webs which they spin close to the ground.

The Chilopods are spread over all parts of the earth, but the species of temperate countries are mere pygmies when compared with some inhabitants of the tropics. They are all shunners of light, retiring during the day to hiding-places in the ground, under stones and the bark of trees, and in the crevices of rocks, buildings, &c., and coming forth at night in search of their food, which consists of insects, worms, and other small animals. When disturbed, most of them run with considerable rapidity, and with an undulating, more or less snake-like, movement of the body; and if seized or otherwise interfered with they have no scruples about making use of the formidable nippers formed by the second pair of limbs. The poisonous secretion which, as already stated, is poured forth through the perforated point of these organs, renders the bite of the larger species very formidable; but even the small British species, such as *Lithobius forficatus*, will attempt to bite the fingers of their captor in a most savage manner. The order may be divided into two families, the first of which includes only a comparatively small number of curious forms, while the second comprises the great majority of the species, which vary considerably in character.

FAMILY I.—SCUTIGERIDÆ.

The Myriopods forming this family are remarkable for the great length of their limbs and antennæ, the latter, and frequently some of the former, being longer than the body of the animal. They are further distinguished by the possession of a pair of regular compound eyes, by the great

length of the jointed part of the first pair of limbs, which project like palpi from the sides of the head, and by the small number of body-segments. These would appear to be fourteen besides the thoracic segments, but the dorsal plates are enlarged so that the alternate ones cover those lying immediately behind them, and thus the body shows eight dorsal and fifteen ventral plates. The dorsal plates are rounded behind and deeply notched in the middle, and in each notch a stigma is situated. The legs correspond in number to the ventral plates, and are long and slender, increasing in length towards the posterior end of the body. The tarsi are very long, whip-like, of two parts, and finely annulated.

These curious creatures, although by no means numerous, are spread over the greater part of the earth's surface, but abound more especially in warm countries. They are exceedingly active, and run freely up perpendicular surfaces. The largest known species is the *Scutigera nobilis* from India and the Mauritius, which measures two inches in length; the best known European species is *Scutigera coleoptrata*, which inhabits the south of Europe and north of Africa, and is about four-fifths of an inch long.

FAMILY II.—SCOLOPENDRIDÆ, OR CENTIPEDES.

The members of this family are more elongated and have a greater number of body-segments than those of the preceding group; the antennæ are shorter than the body; the organs of vision, when present, consist of groups of ocelli placed on the sides of the head; the jointed appendages of the first thoracic ring do not protrude, and have a small claw at their extremity; the legs are of moderate length and inserted close to the ventral plates, which reach the sides of the body;

SCUTIGERA FORCEPS FROM NORTH AMERICA. (Nat. Size.)

and the stigmata are placed in alternate segments, in the membranous portion which unites the dorsal and ventral plates. The tarsi consist of one or two joints, which are not annulated.

These creatures, the best known of which are called Centipedes, or Galley Worms, are distributed nearly all over the world, and everywhere they display the same general habits, being ferocious animals of prey, lurking in dark places and in the ground, and using their formidable footjaws for the destruction of their prey and their defence against enemies. The tropical species are gigantic in comparison with the European ones, which are not numerous. The best known European species belong to a genus (*Lithobius*), which is the type of a peculiar sub-family LITHOBIIDÆ, characterised by having numerous ocelli on the sides of the head, and the second thoracic segment represented by a dorsal plate. Thus there are sixteen segments with dorsal plates behind the head, and fifteen of these are provided with ambulatory legs. Several species occur in Britain, and of these the commonest (*Lithobius forficatus*) is found all over Europe. It is usually about an inch long and of a shining reddish-brown colour, with the head and antennæ redder and the legs yellowish, and it occurs almost everywhere in the ground, under stones and the bark of trees, and in cellars and dark outhouses.

In the true SCOLOPENDRIDÆ, a few of the smaller species of which occur in Europe, while the majority and all the largest forms are inhabitants of tropical and sub-tropical regions, the ocelli are never more than four in number, but the segments of the body are more numerous than in *Lithobius*, being always over twenty. One of the largest European species (*Scolopendra cingulata*, p. 153) is three inches and a half long, and is found in the south of Europe, and especially in France. It is of a rusty yellow, with the head and antennæ and a central band and the margins of the segments green. In India and South America several species attain a length of nine or ten inches, and we have seen

specimens from the forests of the equatorial part of the latter region over a foot in length. According to Ulloa, Centipedes were to be seen in Carthagena in his day three feet long and four or five inches broad.

The GEOPHILIDES, which are entirely destitute of ocelli, differ further from the preceding in having the body extremely long and slender, composed of from fifty to over one hundred segments. The tarsi are of a single joint. Some of the exotic species of this group attain a great length and an enormous number of segments. Thus *Geophilus cumingii*, from the Philippines, is five inches long, and contains 160 segments, and *G. gabrielis*, from the Canaries, grows to a length of over seven inches, and shows 163 pairs of legs. A good many *Geophili* inhabit Europe, and we have several in Britain, such as *Geophilus longicornis*, which grows to a length of three inches, and has fifty-five pairs of legs, and *G. subterraneus*, a species half an inch longer and with a considerably larger number of segments (seventy-eight to eighty-three). Both these species are common, and may frequently be turned up in garden ground, where they live upon the larvæ of insects and other soft-bodied creatures met with in such situations. *Geophilus longicornis* is luminous in the dark, and another British species has received the name of *Geophilus electricus*, on account of its manifesting the same property very strikingly.

ORDER II.—CHILOGNATHA.

In this second order of Myriopoda the head is usually large and placed perpendicularly, and all the three so-called thoracic segments have the dorsal part freely developed; nor are the limbs of the first two segments converted into organs connected with the mouth. The number of body-segments varies between nine and eighty or more, and the form of the segments is also very variable, but each apparent segment beyond the fourth or fifth is furnished with two pairs of legs, and with two pairs of regular stigmata placed near the origin of these limbs. The limbs are sometimes deficient on the first thoracic segment. In internal structure the Chilognatha present some peculiarities. The main tracheæ do not unite after the insect type, but form branching tufts, the fine ramifications of which run to the neighbouring organs; and the organs of reproduction in the great majority do not open at the posterior of the body, but in the coxæ of the second or third pair of legs. The males are provided with peculiar copulatory organs in the sixth or seventh segment, which in this case wants one or both pairs of legs. The eggs are deposited in a mass in a cavity of the earth. The form of the newly-hatched young, and its progress towards the adult condition, have already been indicated (see figures on p. 152). The presence of two pairs of limbs upon each ring of the body would seem to show that these may be really equivalent to two segments united. We may recognise the following four families:—

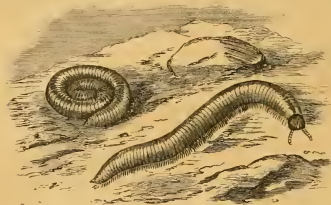
FAMILY I.—JULIDÆ, OR MILLEPEDES.

The Julidæ, commonly known as Millepedes, from the great number of their legs, sometimes called Galley Worms, a name which more properly belongs to the Scolopendridæ, and sometimes, erroneously, Wire Worms, have usually a long cylindrical body, composed of segments which form a complete horny ring, the dorsal plate surrounding the whole body, with the exception of a very small sternal piece firmly united to it by sutures, in which piece are situated the insertions of the legs and the small stigmata. The bases of the legs are thus brought close together and to the middle line of the body. The head is large, with short antennæ, and aggregated ocelli, which, however, are sometimes entirely wanting; and the mouth is formed for biting.

These animals are distributed in all parts of the world, the largest species occurring in the tropics. They are nocturnal, and live in or on the ground, and under stones and the bark of trees. They move slowly, creeping along by means of their short and slender legs, the motion of which presents a curious spectacle. Their food consists of both animal and vegetable matters; they also attack fleshy, growing roots, a propensity that often causes them to be mischievous. The species are numerous, and most of them have the power of emitting an acrid fluid of disagreeable odour from small apertures pierced in the dorsal part of the segments, which have been mistaken for stigmata by some observers. One of the best known species is the *Julus sabulosus*, a dark greyish-brown or blackish creature, about one inch and a half long, with the borders of the segments lighter, and two reddish lines down the back; and another, perhaps equally abundant, is the *Julus terrestris*, which is similar, but rather smaller, and destitute of the two reddish dorsal

lines. Both these species are common in Britain and most parts of Europe. Some British and European species are considerably larger than these, but the giants of the family are to

be sought within the tropics, species of the genera *Spirostreptus* and *Spirobolus* inhabiting India, Africa, tropical America, and the West Indies, attaining a length of from six to nine or ten inches. All the species have the power of rolling themselves up into a spiral form with the legs concealed.



JULUS TERRESTRIS.

separated by a distinct sternal piece. In general habits they resemble the Julidæ, and are chiefly found under bark, where they are often abundant. They generally have no eyes, and the number of segments is twenty; they are also more or less depressed, and thus present a general resemblance to the Scolopendridæ.

FAMILY II.—POLYDESMIDÆ.

These animals are very nearly related to the preceding, but although the dorsal plate is continued on to the ventral surface, it is generally furnished with a dilatation at the sides, and the insertions of the limbs are

FAMILY III.—SIPHONIZANTIA.

This is another family allied to the Julidæ, but differing from it in more important characters than the preceding. The body is semi-cylindrical, and the dorsal plates of the segments encroach only a little upon the under surface. The head is small, and concealed beneath the margin of the first segment; and the clypeus in combination with the organs of the mouth, which are united, forms a sort of conical sucking organ. The legs are short, and do not project beyond the sides of the body. The species, which are few in number, are of comparatively small size, but consist of numerous very short segments. They are found in rotten stumps of trees. One species (*Polyzonium germanicum*), about half an inch long, is found on the continent of Europe, especially in Germany and Poland. The rest are for the most part exotic.

FAMILY IV.—GLOMERIDÆ.

The Glomeridæ are short ovate forms much resembling the common Wood Lice, with some of which they also agree in their power of rolling themselves into a ball. They are convex above, and composed of twelve or thirteen segments, of which the dorsal plates extend only to the margins, within which, on the lower surface, there are pleural plates separating the dorsal plates from the points of insertion of the legs. The number of pairs of legs varies between seventeen and twenty-one. Several species inhabit Europe, and most of the exotic forms belong to the Eastern Hemisphere. They may be compared to abbreviated Julidæ, and are like them in their habits.

ORDER III.—PAUROPODA.

This order has been established for one or two curious little creatures discovered by Sir John Lubbock during his investigations on the Thysanura, to which, apart from the presence of limbs on all the segments, they present a considerable analogical resemblance. These little animals consist of eight segments besides the head, and these segments bear a good many short and a few long bristles. The head also is sprinkled with hairs. The first segment of the body has a single pair of legs, while each of the following segments to the fifth bears two pairs, and may consequently be regarded as double; in fact, the divisions are recognisable beneath, and Sir John Lubbock, reckoning the head to be composed of two segments, assigns fourteen primitive segments to the whole body. The most remarkable character, however, is to be found in the antennæ, which are five-jointed and branched, with one branch terminated by a long, minutely-jointed lash; while the other has two shorter ones, between the bases of which is placed a peculiar appendage, sometimes supported on a footstalk. Such a structure of the antennæ reminds one rather of the Crustacea than of any air-breathing Arthropod.

Another peculiarity of these animals is that they appear to possess no respiratory organs. There are no stigmata, and although the skin is very transparent, Sir John Lubbock could detect no tracheae in the interior of the body. The commonest British species (*Peripatus huxleyi*), which attains a length of one-twentieth of an inch, is an active little white creature, which may be found throughout the year among dead leaves and decaying vegetable matter in general. Two oval spots on the head are supposed to represent eyes. It appears to breed in the early autumn, and the newly-hatched young have only three pairs of legs. Sir John Lubbock describes a second but rarer British species (*P. pedunculatus*), and others have been obtained in North America.

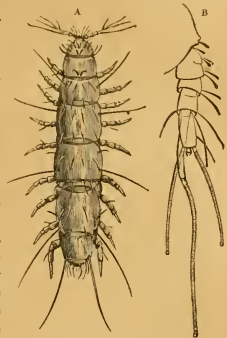
ORDER IV.—ONYCHOPHORA.

Many years ago the Rev. Lansdowne Guilding discovered in the island of St. Vincent a curious worm-like creature frequenting dead wood and the stumps of trees, which he regarded as probably a worm, and described (in 1825) under the name of *Peripatus juliformis*. Its true position has been frequently discussed, and for a long time it seemed to hover between the Annelids and the Myriopods, until the investigations of Professor Moseley, during the voyage of the *Challenger*, caused the scale finally to descend on the Myriopod side. These creatures are convex and worm-like, with their segmentation not particularly distinct, and the integuments of all parts of the body soft. On each side of the body are a number of short legs, terminated by a rudimentary jointed part, and a pair of hooked claws. The head bears a pair of simple, annulated antennae, and a pair of simple eyes; the mouth, which is below, has tumid lips, and within these two pairs of horny jaws. Respiration is effected by means of tracheae, which, however, are not connected into a regular system, but each respiratory aperture, of which a great number are scattered over the skin of the animal, gives origin to a small branched tuft of breathing tubes. As Professor Moseley says, we



PERIPATUS CAPENSIS. (Nat. Sic.)

have here probably the first stage in the evolution of tracheae, which would indicate that the "air-tubes were developed in the first tracheate animal out of skin glands scattered all over the body." Of the internal structure of *Peripatus* we need only say that it differs from that of normal Myriopoda in the wide separation of the ventral nervous cords, and that it has greatly developed glands, called by Professor Moseley "slime glands," probably homologous with the salivary glands of other Myriopods, which secrete in abundance a clear viscid fluid. This is ejected by the animal from a pair of papillae placed at the sides of the mouth, in fine, thread-like jets, which combine to form a sort of network in front of the animal. It would appear that the emission of this slime is partly for defensive and partly for offensive purposes, as it takes place when the creature is irritated or handled, and is also employed, according to some observers, in the capture of insects for food. The *Peripati* are viviparous. They reside principally in rotten wood, are nocturnal in their activity, and walk in the manner of caterpillars, with the body much extended. According to Professor Moseley's observations on the Cape species (*Peripatus capensis*), the food consists of vegetable matters; but according to Professor Hutton the New Zealand one (*P. novae-zealandiae*) feeds partly upon insects. The *Peripati* must be regarded as representing a very early stage in the evolution of the Arthropods from the Vermes, and hence their form is probably of great antiquity. Their peculiar geographical distribution would also point in the same direction, seeing that species of the genus are found in Central America and the West Indies, in Chili, New Zealand and Australia, and at the Cape of Good Hope.



PERIPATUS HUXLEYI.

A, enlarged 40 times. B, antenna, enlarged 250 times.

CLASS ARACHNIDA.

CHAPTER I.

SCORPIONS AND SPIDERS.

ARACHNIDA—General Characters—Internal Structure—Habits—Distribution—Fossil Forms—Classification—Order ARTHROGASTRA—Lung-sacs—Classification—Family SCORPIONIDÆ—Scorpions—Family PHRYNIDÆ—Family CHELIFERIDÆ—False Scorpions—Family PHALANGIDÆ—Harvest-men—Family SOLPUGIDÆ—Galeodes—Order ARANEIDA—True Spiders—General Characters—Internal Structure—Spinning Apparatus—Habits—Classification—TETRAPNEUMONES—Family MYGALIDÆ—Bird Spiders—*Mygale*—Trap-door Spiders—DIPNEUMONES—Family SALICIDÆ—Salticidae—Salticidae—Family LYCOSIDÆ—Citigrade—Tarantula—Family THOMISIDÆ—Laterigrade—Crab Spiders—Family TEGENARIIDÆ—Tubitels—House Spider—Water Spider—Family THERIDIIDÆ—Inequitels—Malmignatte—Family ERETRIDÆ—Orbitels—Garden Spider.

IN both the preceding classes of air-breathing Arthropods, the head is furnished with a pair of jointed organs recognisable as antennæ; in the Arachnida we find no antennæ of the same kind, but the corresponding parts, when present, are converted into a pair of more or less jaw-like organs. Except in two groups the head is always intimately united with the thorax to form a single mass, called the cephalothorax, which bears in front all the organs pertaining to the head, and on its lower surface the thoracic limbs; in many cases even the distinction between thorax and abdomen is effaced. There are no wings. The organs of respiration, when present, consist either of tracheæ, or of peculiar sac-like modifications of tracheæ, to which the name of lungs or pulmonary sacs has been given. The abdomen is always destitute of limbs. The range of organisation is so great in the Arachnida that it is somewhat difficult to give any general description of the class, and we shall therefore only indicate briefly what is necessary to make the following descriptions of the orders and families intelligible.

The cephalothorax is usually covered above by a single plate, upon the anterior part of which the eyes, when present, can be seen. These are always ocelli or simple eyes, and they vary in number between two and twelve. The organs representing the antennæ are articulated to the front of the cephalothorax above the opening of the mouth, and receive their nerves from the supraœsophageal ganglion; they usually take the form of jaws, often of formidable dimensions, and in function replace the true mandibles, which are absent. They are commonly called *falces*. Of the two pairs of organs representing the maxillæ and labium of insects, the former (*maxillæ*) retain their position as organs of the mouth, their basal parts closing the mouth behind either as separate pieces, or united into a single plate, while their jointed palpi project, and frequently acquire the form and size of an additional pair of limbs. Of regular limbs the Arachnida have four pairs, of which the first may be considered to represent the labial palpi, and the others the three pairs of legs of the Insecta. The bases (*coxæ*) of all these limbs surround the sternum, but possess apparently little power of motion. The limbs springing from these *coxæ* consist, in the higher Arachnida, usually of seven joints, namely, a *trochanter*, which is sometimes elongated, but generally very short, a stout femur, a *tibia* composed of two unequal joints, and a *tarsus*, also consisting generally of two joints, which are sometimes annulated, and the last of which bears the claws and often other subordinate organs. In the lower types of the class of course the limbs are frequently simpler in construction, and occasionally they are represented only by rudimentary parts.

The abdomen is attached to the cephalothorax sometimes by a slender peduncle, sometimes by its whole width; and in certain of the lower forms of the class the whole animal shows no traces of divisions. In some instances also the abdomen itself is clearly divided into a larger or smaller number of segments, whilst in others no trace of segmentation is apparent. The skin covering the body of the Arachnida is generally soft and leathery, with the exception of the limbs, the joints of which are more or less horny tubes. In other cases the whole surface is horny. The skin is changed repeatedly and throughout the life of the animal, there being no fixed period for the final moult, as in the insects; thus the Arachnida, after having reached the reproductive stage, may continue to live and increase in size, and produce successive broods of young.

The mouth in the Arachnida leads into a narrow œsophagus, which in some forms (Scorpions) passes directly into the stomach, while in the majority it is clearly separated from the latter. The stomach itself presents the remarkable peculiarity that in most cases it gives origin on both sides to several cæca, often of the same number as the limbs, which in many cases actually penetrate

more or less into them. The length of the intestine generally corresponds with that of the abdomen, at the extremity of which it opens. The amount of convolution is not great. Before its termination it generally enlarges into a rather large cloaca, immediately above which the Malpighian vessels open into the intestine. The so-called fatty body of the Insecta does not occur in this class, but of the body-cavity is filled with the lobes of a greatly-developed liver, in which the other internal organs are imbedded; the numerous gall-ducts proceeding from this liver unite to form eight or ten main ducts, which open into the sides of the intestine at some distance behind the stomach. Salivary glands discharging into the cavity of the mouth are also generally present.

The organs of circulation and respiration show very great differences in the class Arachnida. The lowest types have no special organs of the kind. Others possess a dorsal vessel of very simple construction; while the higher forms, such as the Spiders and Scorpions, have a regular chambered dorsal vessel or heart, into which the blood penetrates through valvular apertures, while part of it issues again through small arteries given off by the chambers, and the rest through an aorta, which divides into numerous branches, distributed through the body. In the lower forms again respiration is performed by the agency of tracheæ like those of insects and Myriopods; in the more highly-organised groups, while simple tracheæ are still frequently present, the chief respiratory organs are peculiar lung-sacs, of which the ventral surface has from one to four pairs, and which show in their interior several delicate membranous folds. The nervous system exhibits almost an equal amount of variation, but in its highest development it shows an œsophageal ring with a large ganglion above the œsophagus, from which nerves are supplied to the eyes and falces, and another below the œsophagus, often united with the great ganglionic mass of the cephalothorax, and from these combined nerves issue to the organs of the mouth proper and the four pairs of legs. When the abdomen shows distinct segments, it also contains a ventral chain of ganglia united by commissures. Except in one small and lowly group, the Arachnida are all of separate sexes, and with but few exceptions they are oviparous. Many of them undergo more or less change of character in advancing towards maturity, and in some parasitic forms we find examples of retrograde metamorphosis.

In their habits the Arachnida are nearly all carnivorous, and, indeed, predaceous, living principally upon various insects and other weaker Arthropods, of which they usually content themselves with sucking out the juices, sometimes, however, devouring part of the solid substance. Among the lower forms, some feed upon solid materials of animal origin, and others upon vegetable matters, whilst some are parasitic, not only upon other Arthropods, but even upon vertebrate animals. They are mostly terrestrial creatures, but one whole order consists of inhabitants of the sea, and a few members of other groups are also aquatic in their habits. Their distribution is world-wide, but, as in most other groups, tropical countries possess the greatest number of species, and present us with the largest and most remarkable forms. Geologically, the class is of great antiquity. Unmistakable Arachnida, of forms which stand high in our classifications, occur in the Coal Measures of various parts of the world. Scorpions and true Spiders are recorded from these deposits both in Europe and in America, which also contain other forms, the precise location of which is more difficult. Fossil Arachnida also occur, although sparingly, in later deposits containing insect remains, such as the lithographic slates of Solenhofen and the various Tertiary insect-beds, and, as might be expected, Spiders are by no means uncommon inclusions in amber.

The vast range of characters presented by the multifarious members of this class, the highest and lowest of which, but for the existence of the intermediate forms, would hardly be referred to the same group, renders the classification of the Arachnida rather complex, and has given rise to considerable diversity in the systems adopted by different authors. Formerly the class was divided into two principal groups, Pulmonata and Tracheata, according as the animals breathed by lung-sacs or by tracheæ, but this mode of division has been held to be unsatisfactory on account of the analogy between the so-called lungs and the tracheæ, and the further fact that lungs and tracheæ co-exist in many forms. The actual difference in the arrangement of the groups by the abolition of this mode of division is so insignificant that it is really of little consequence whether we retain it or not, and as the mode of arrangement in accordance with the general characters presented by the various groups is perhaps more easily intelligible, we may adopt it in the present work. The following table will show the orders into which we propose to divide the class.

- | | |
|---|------------------------|
| I.—Abdomen composed of distinct segments | Order 1.—ARTHROGASTRA. |
| II.—Abdomen with no distinct segments or rudimentary :— | |
| A. Abdomen distinctly separated from the cephalothorax, pedunculate | 2.—ARANEIDA. |
| B. Abdomen not separated from the cephalothorax :— | |
| * Furnished with tracheæ | 3.—ACARINA. |
| + With no distinct organs of respiration :— | |
| a. Body indistinctly ringed ; four pairs of stumpy legs | 4.—TARDIGRADA. |
| b. Body worm-like ; internal parasites | 5.—LINGUATULINA. |
| c. Cephalothorax of four segments ; legs long ; abdomen rudimentary | 6.—PANTOPODA. |

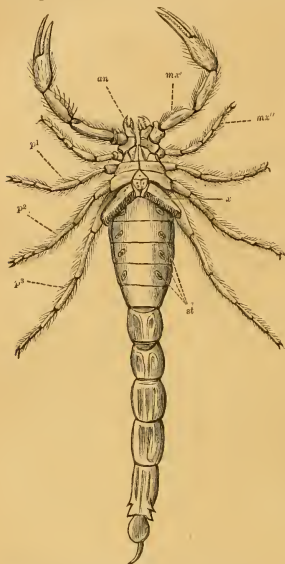
The first of these orders includes the Scorpions, and some other Pulmonate forms, together with the long-legged Harvest-men, the Book Scorpions, and some others which breathe by tracheæ ; the second is formed by the true Spiders, in which we find lung-sacs as well as tracheæ ; the Acarina include the numerous species of Mites, in which tracheæ are the sole organs of respiration ; the Tardigrada are the minute creatures known to microscopists as Bear animalcules ; the Linguatulina, when adult, are worm-like creatures, with a couple of

hooks as the sole representatives of limbs, but in the young state show arachnidan characters ; and the last order consists of some marine creatures, which may be called Sea Spiders, and which have been banded about between the Crustacea and the present class.

ORDER I.—ARTHROGASTRA.

This order includes several distinct types, of which, indeed, separate orders have been made by many zoologists, and it is not without some hesitation that we have accepted it in its present signification. The sole important character by which all its members are held together, is the possession of a distinctly segmented abdomen, which is attached to the hinder part of the cephalothorax by its whole width ; in other respects we find a great variety both in external structure and in internal anatomy.

In respect of the respiratory organs especially, we find two perfectly distinct types, some forms belonging to the group breathing exclusively by lung-sacs, while the rest are as exclusively tracheal in their respiration. These lung-sacs, which occur in the highest types of this order, and associated with tracheæ throughout the next, are regarded by anatomists as modifications of tracheary organs. They are situated in pairs in one or more segments of the abdomen, and each of them communicates with the external air by a more or less slit-like opening, or stigma, pierced in the ventral plate of the segment. This aperture leads into a small, usually flattened, sac, the walls of which are folded so as to form a number of delicate lamellæ (from 20 to 100, in different cases) dividing the cavity into so many narrow compartments, all opening into a common chamber which communicates with the outer air through the stigma. As



UNDER SURFACE OF SCORPIO OCCITANUS.

an, falcæ, representing antennæ ; m¹, first pair ; m², second pair of palpi ; p¹, p², p³, true legs ; x, comb ; st, stigma.

Professor Huxley remarks, "the organ, in fact, somewhat resembles a *porte-monnaie* with many pockets." The blood circulates through these delicate membranous folds, and is thus exposed to the influence of the air, which has free access to the cavity of the sac ; it is then conveyed by sinuses to the pericardial cavity, to pass thence into the heart. According to Professor Huxley the expiration of the air is effected by the agency of peculiar muscles which act on

the membranous lung-sacs; some zoologists also believe that inspiration is caused by a similar agency. The true tracheæ, when present, are analogous to those of the Insects and Myriopods, open like them by stigmata, and ramify throughout the body.

The great diversity of organisation presented by the members of this order renders their division into families exceedingly clear and distinct, and we may recognise with facility the following five groups:—

I.—Respiration by lung-sacs (*Podipalpi*).

- a. Maxillary palpi with nippers; stigmata four pairs; terminal segments of abdomen forming a slender tail, with a sting at the end
- b. Maxillary palpi with imperfect nippers, or simple; two pairs of stigmata; no caudal sting

II.—Respiration by tracheæ (*Adelarthrosomata*).

a. Cephalothorax not segmented:

- * Maxillary palpi with nippers
- † Maxillary palpi simple
- b. Cephalothorax divided into four segments

Family 1. SCORPIONIDÆ.

„ 2.—PHRYNIDÆ.

„ 3.—CHELIFERIDÆ.

„ 4.—PHALANGIDÆ.

„ 5.—SOLPUGIDÆ.

FAMILY I.—SCORPIONIDÆ.

The species of this family are exceedingly uniform in their structure. They consist of a rather broad anterior part, composed of the cephalothorax and seven distinct segments following it, at the hinder extremity of which come five narrower segments forming a sort of tail, terminated by a bulbous piece having a short but sharp point. At the front we see a pair of jointed organs having regular nippers, like the so-called claws of a Crab or Lobster, and behind these four pairs of ambulatory limbs. The type is so interesting and important, however, that we must describe its structure a little more particularly.

The upper surface of the cephalothorax is covered by a shield-like horny plate, upon which from three to six pairs of simple eyes are to be seen, a pair of extra size being placed close to the middle

line of the shield, while the rest are arranged variously towards the margin, according to the genera and species. The seven plates which follow this cephalothoracic plate on the back of the animal represent so many abdominal* segments, but are connected with the corresponding sternal plates only by soft skin, with the exception of the seventh, which joins its sternal plate at the hinder part. The other six dorsal plates have only four distinct sternal plates to correspond with them, and



ANDROCTONUS (OR SCORPIO) OCCITANUS.

* Prof. Huxley speaks of them as thoracic.

these appear to represent the third, fourth, fifth, and sixth; each of them presents a pair of stigmata leading into lung-sacs. The five segments following these, which form the wider part of the body, consist of complete horny rings, or rather short tubes, articulated in such a manner as to give the tail, which they form, considerable freedom of movement. The last joint of this tail, regarded as the equivalent of the telson of the Crustacea, is a bulbous piece, swollen at its base, and narrowed and curved into a hook at the free end; the bulb contains a pair of glands which secrete a poisonous fluid, which is conveyed by ducts to the minutely but doubly perforated point of the hook, and renders the sting of the Scorpion so formidable an offensive weapon.

In the Scorpions, as in most Arachnida, the representatives of the antennæ, which spring from beneath the front margin of the first dorsal piece, are a pair of organs affiliated to the mouth, but in the present group, instead of forming two-jointed jaws, the chelicere are composed of three joints, the last two of which form small pincers. A large labrum is followed by a very small mouth-aperture, on each side of which are the bases of the maxillæ, which are true foot-jaws, having a distinct masticatory surface, while their elongated palpi are the large pincer-like organs which form so striking a characteristic of the Scorpions. Of the four pairs of walking limbs which follow these chelate palpi two have their basal joints forming part of the boundary of the mouth, a circumstance which has led some anatomists to regard them as representing the maxillæ and labium, and the large palpi as belonging to the mandibles. The ambulatory limbs are provided with three claws. Behind the origin of these limbs are traces of the sternal portions of the first and second free segments, the first bearing the valves which cover the generative aperture, while the second supports a pair of very singular comb-like appendages, the function of which does not seem to be very clearly made out.

The alimentary canal, which starts from the minute aperture of the mouth, forms a simple tube continued through the whole length of the body, and opening in the segment immediately preceding the sting.

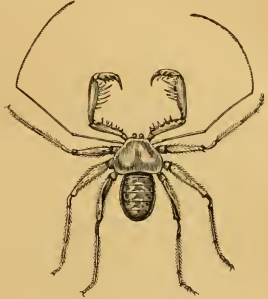
The Scorpions are the largest and most formidable members of the class Arachnida, and they are for the most part confined to the warmer regions of the earth. In Southern Europe, indeed, a few species are found, and some of these are of moderate size, such as the *Androctonus occitanus*, which occurs throughout the Mediterranean region, and measures upwards of three inches in length, but in hot countries there are Scorpions of nearly double this stature. The genus (*Androctonus*) to which the largest European Scorpion belongs, is chiefly represented in Africa, although its members also occur in Western Asia, as well as in Europe. Its name, which signifies "Man-killer," indicates the dread with which these creatures are regarded in Africa, where their sting is certainly productive of very painful consequences, although whether it is ever fatal would seem to be still a matter of some doubt. The European species, at any rate, do not appear to produce any very serious effects. *Androctonus occitanus* is said to be the least formidable species of its genus; and the other common European Scorpion (*Scorpio europæus*) is not half the size of its companion. Both these species are to be met with in the south of France, and the second extends its range northward into Germany.

The Scorpions are light-shunning animals, concealing themselves during the day in the ground under stones and in crevices in rocks and buildings. In the twilight they come forth in search of their prey, which consists principally of large insects and their larvæ, and spiders, and when thus engaged they carry the long flexible tail elevated over the back of the body, so that the sting is about as far forward as the cephalothoracic plate. The prey is seized by the pincers of the large palpi, and then pierced by the sting and speedily killed. Scorpions generally live quite alone, and select dry places for their abode. Brought together accidentally, they will usually fight, and if one is killed the other will feed upon it; the male also, being smaller than the female, is obliged to be very cautious in his approaches to the object of his affections, lest he should be treated in the same manner. The females are viviparous, that is to say, the eggs are hatched in the enlarged oviducts, and the number of young produced may reach sixty. In their earliest days the young Scorpions are carried about upon the back of their mother.

FAMILY II.—PHRYNIDÆ.

The Phrynidæ constitute a small family of Arachnida nearly related to the Scorpions, from which they nevertheless differ in some sufficiently striking particulars. The fore part of the body is also

occupied by the dorsal plate of the cephalothorax, and this has eight ocelli, of which two, as in the Scorpions, are placed close to the middle line. The falces consist of two joints, with an apical claw; the true maxillary palpi are large and stout, and terminate either in a simple claw or in an imperfect pincer, in which the movable finger is considerably shorter than the other; while the second palpi, or first pair of legs, are long and slender, and terminated by a finely annulated tarsus. The three pairs of true legs are comparatively stout. Attached to the posterior end of the cephalothorax is the abdomen, which is flat, slightly narrowed towards the base, and composed of eleven or twelve segments; it has no comb-like appendages at its base, and the hinder extremity is not narrowed into a flexible tail armed with a sting, as in the Scorpions, although in one genus (*Thelyphonus*) the last three segments are much reduced in size, forming a short tube, terminated by a long, jointed filament. The respiration is effected by lung-sacs, the stigmatic openings of which are situated near the hinder margin of the second and third ventral plates; the sacs contain numerous lamellæ (about eighty in some species).



PHRYNUS RENIFORMIS.

Although destitute of the formidable sting of the Scorpion, the attacks of these creatures, which are mostly of considerable size, are dreaded by the inhabitants of the countries in which they occur. No doubt the pointed claw of the falces is perforated and connected with a poison gland, as in the true Spiders, and it is by means of these organs that painful wounds are inflicted. In their general habits the Phrynidæ much resemble the Scorpions, with which they also agree in the tubular structure of the alimentary canal. They are not numerous in species, and form only two principal genera, which, however, are represented in the tropical parts of both hemispheres, although the species are most numerous in America. They are generally from an inch to an inch and a half in length, but a species five inches long (*Thelyphonus giganteus*) has been described from Mexico. This, however, includes the annulated tail characteristic of the genus *Thelyphonus*, which is often of considerable length. In the genus *Phrynus*, in which the tail is wanting, the second pair of palpi are very long, sometimes three times the length of the body. The species of *Phrynus* are viviparous.

FAMILY III.—CHELIFERIDÆ.

This family comprises a great number of little creatures, which, in appearance, are exactly comparable to minute flattened Scorpions that have lost their tails; they are known as False Scorpions and Book Scorpions. Like the Scorpions they have the first palpi developed into long didactyle chela, and the second pair in the form of legs, but their basal part forms no part of the boundary of the mouth; the falces (representing the antennæ) are much reduced, and the surface of the cephalothorax, which is often divided into two parts by a transverse furrow, bears only one or only two pairs of eyes. Behind the cephalothorax follows a broad, flat abdomen, composed of eleven similar segments, and without any comb-like appendages at its base. On the first two abdominal segments are placed two pairs of stigmata, opening, however, not into lung-sacs but into regular trachææ, which give off branches to the organs of the body in the same way as in the remaining families of the order, and in the second segment is the opening of the sexual organs, close to which are some silk glands, with the secretion from which the little creatures are said to manufacture protective coverings for themselves when they are about to change their skin, or to lie by for the winter.



CHELIFER CANCRIVORUS.

These little creatures, few of which exceed a sixth of an inch in length, are tolerably numerous, and inhabit most parts of the world. They are generally of different shades of brown, and have the limbs and frequently the cephalothorax paler than the rest of the body. Like the preceding groups

they lead a concealed life, making their way into any confined spaces in search of food and shelter. One of the best-known species, the so-called Book Scorpion (*Chelifer concroides*), is very common in old houses, where it often lives in and among old dusty books and portfolios, whence its popular name. It is about an eighth of an inch long. Several allied species (*Chelifer muscorum*, &c.) are found chiefly in moss, while others may be met with in hot-beds and among decaying vegetable matters, upon the ground under herbage, and under the loose bark of trees. They run freely in all directions, and when alarmed hold up their little pincers in a threatening manner. Their food consists of the minute insects, mites, &c., which they meet with in the various places haunted by them; and the females are oviparous, usually producing about twenty eggs. The common house species, and probably some of the others, have the curious habit of attaching themselves by their pincers to the legs of flies, which may occasionally be found flying about thus loaded. Their object in this manœuvre does not seem to be understood.

FAMILY IV.—PHALANGIIDÆ.

The Phalangiidæ, or Harvest-men as they are often called, constitute a second family of tracheate Arachnida, and some members of this must be tolerably familiar to most of our readers. They have a short, thick body, with an unsegmented cephalothorax, to which the abdomen, usually composed of six distinct segments, is attached by the whole width of its base; the chelicere are three-jointed and terminated by pincers, as in the Scorpions; the first maxillary palpi are of moderate length, and terminated by a simple claw; while the second pair, and the three pairs of legs, are usually of great length and slenderness, so that the creatures walk along as if mounted upon stilts. In some exotic species, however, the legs, or some of them, are shorter and stouter, and curved or furnished with processes which add to their grotesque appearance. The tarsi consist of numerous joints, and are sometimes exceedingly long and slender. The cephalothorax bears two ocelli. Respiration in these animals is effected solely by tracheæ, which open by a single pair of stigmata, each furnished with a valve, situated between the coxæ of the last pair of legs and the base of the abdomen. The Phalangiidæ are oviparous, and the reproductive aperture is situated quite at the base of the abdomen between the coxæ, and from it the female can protrude a long ovipositor.

The Phalangiidæ are numerous in species, and generally distributed over the earth's surface, although their metropolis would appear to be South America, where also they display the most remarkable forms. The species of temperate climates, and many of those of the tropics, have the legs exceedingly long and slender, and similar in their development, like the species so common in our gardens and fields. The best-known of these (*Phalangium opilio*) is rather less than a quarter of an inch long, of an ashy or yellowish grey colour, paler below. The female has a blackish band on the back, and the male an erect horn on the chelicere; the cephalothorax, coxæ, and femora are finely spined. This species may be found almost everywhere, but especially on walls and the trunks of trees, and although it frequently lurks in dark corners, obscurity does not seem to be so much an object with it as with many other Arachnida. Still its greatest activity is in the evening, when it wanders about in search of small insects, mites, and spiders, which it captures by a sudden rush. According to some observers, these animals take more than a year to arrive at their maturity.

The abdomen is always of comparatively small size in these animals, but in many of the South American species of *Gonypletes* and allied genera this part is still further reduced and almost completely concealed under the cephalothorax, which at the same time attains a somewhat increased size. This peculiarity, coupled with a remarkable development of the hind legs, renders these South American forms peculiarly grotesque. The posterior coxæ are enormously developed, so that the limbs of which they form a part seem to spring from points entirely behind the posterior end of the body, and the component parts of the legs, which are generally a good deal thicker than their fellows, are curved into various forms, and generally armed with spines and processes of different kinds.

FAMILY V.—SOLPUGIDÆ.

The Harvest Spiders of the last family are considerably more spider-like than the members of any of the three preceding ones, and in those of this fifth family we have to do with creatures which any one would denominate "Spiders," although they present, at all events, one character which

separates them not only from the Spiders proper, but from all but the last and most problematical order of the Arachnida, namely, the constitution of the cephalothorax out of four distinct rings. In point of fact, we may say that a true cephalothorax does not exist in them, but that it is represented by the head and three thoracic segments. The form, however, is exactly that of a true Spider, while the segmentation agrees rather with that of an insect, and in some respects the animals are nearly allied to the Phalangiidae.

The head bears a pair of large ocelli, and a pair of enormous chelicerae, greatly inflated towards the base, and terminating in pincers. Both pairs of palpi attain the length and form of legs, so that the animals appear to have five legs on each side, but the apical joints of the palpi have no claws. Behind the head come three distinct thoracic rings, narrower than the head-ring, and each of them



GALEODES ARANEOIDES.

bears a pair of true legs, the coxæ of which stand out freely from the sternum, and the apices of their tarsi have each a pair of claws. Behind the thoracic segments follows the abdomen, which is usually of an elongate ovate or pear shape, and composed of ten segments. The surface of the body is more or less hairy, and all the limbs are especially so. The respiration is by tracheæ.

In walking, these singular creatures use only the three pairs of true thoracic legs, the two pairs of leg-like palpi, of which the first is the larger, being carried in front of them, and no doubt acting as feelers. Their sole weapons are the extraordinarily-powerful, pincer-like chelicerae, of which the lower finger is the movable one; but these are such formidable organs that not only other insects, but even small vertebrate animals, fall victims to their attacks. Like the chelicerae of the true Spiders, they are furnished with poison glands, the secretion from which flows into the wounds that they inflict.

These redoubtable Spiders, which are all of large or considerable size, are chiefly inhabitants of the warmer parts of both hemispheres, but more numerous in species in the eastern than in the western. They live principally in desert places, where they conceal themselves during the day in crevices, or under stones, or in cavities which they dig out in the ground. India and Persia, the great steppes and deserts of Central Asia and Southern Russia, as far north even as Siberia, and the

deserts of Arabia and Africa, are their principal habitations on one side of the Atlantic; on the other side they are best known in Central America and the West Indies. Some small species occur in the southern parts of Europe. Their food consists for the most part of insects, and their chief enemies are the big Centipedes and predaceous Beetles, which, like themselves, run about in search of booty at night.

The commonest and best-known species (*Galeodes araneoides*) is the one found upon the Russian and Asiatic Steppes, which is also believed to inhabit Arabia and Egypt, and probably other neighbouring countries, although perhaps described under various names. It measures sometimes two inches in length. In its nocturnal wanderings, as already described, it carries the two pairs of palpi before it and keeps them in constant motion. If they come in contact with anything they are said to emit a phosphorescent light. Should the object touched be good to eat, the *Galeodes* dashes upon it at once, and its powerful nippers soon make an end of all weaker creatures. Even a Lizard, with a body half as long again as itself, was attacked by a *Galeodes*, seized by the nape, killed, and speedily devoured. Young Musk Rats, and even Bats, shared the same fate; a Scorpion twice its size was seized at the root of the tail and so disabled and destroyed. The successful combatant in this case, however, subsequently attacked a Scorpion in front, and was seized and at once killed with the sting. Captain Hutton, who observed an Indian species, probably *Galeodes futilis*, confirms these results obtained with the Russian species, and adds that his Spider killed a young Sparrow, but did not eat it. The Solpugidae also fight among themselves, when the conqueror devours his victim; but the females show considerable care for their young, which they watch assiduously until they are strong enough to take care of themselves.

Not unnaturally creatures so large and so well furnished with offensive weapons as the ordinary species of this family are regarded with considerable dread in the countries they frequent, and ancient writers even go so far as to declare that parts of India now desert were deprived of their human inhabitants by the fear of these Spiders. From reliable information it appears that their bite is really exceedingly painful, and gives rise, under certain conditions, to very serious symptoms; besides the direct inflammation of the part bitten, temporary paralysis, severe headache, and fainting fits are said to be among the consequences. Domestic animals are also very subject to their attacks, especially camels and sheep, which are either bitten in the feet as they move about, or wounded still more dangerously when they lie down to sleep. The sheep and camels in the summer have their lower surface nearly or quite naked. When they lie down, probably disturbing a *Galeodes* in his search for prey, he avenges himself at once by a severe bite, the consequences of which are so serious that the bitten animal may even die. These Spiders are fond of living among reeds and sedges, and in consequence of this predilection are often brought into the summer dwellings of the Calmucs and other inhabitants of the steppes, in the construction of which such articles play an important part. In this way their contact with man is greatly facilitated. Some thirty or five-and-thirty species are described, all of which are very similar in structure and habits.

ORDER II.—ARANEIDA, OR TRUE SPIDERS.

While the members of the preceding order are for the most part strictly terrestrial in their habits, the true Spiders, to which we have now to turn our attention, exhibit a much greater variety in their mode of life. Many of them, it is true, like the *Arthrogastra* just described, dwell habitually on the surface of the ground, concealing themselves under stones and clods of earth, in moss and other vegetable covers, or even in burrows dug out by themselves; but perhaps an equal number disdain such grovelling habits, wander on trees, shrubs, and plants to any height above the surface, or suspend themselves freely in the air in most ingeniously constructed webs. Some even contrive to get themselves transported through the air, although they possess no wings, by a very remarkable application of the power of silk-producing, which they possess in so great a degree; whilst a few even betake themselves to the water, and construct beneath its surface comfortable little habitations of the most singular kind.

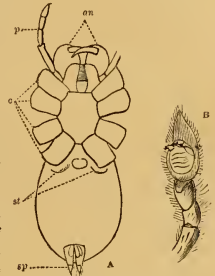
As might be expected in a group of such varied habits, the organisation of these creatures presents considerable diversity, particularly in regard to external form and details, but the main peculiarities of structure distinguishing the order are very uniformly displayed throughout. The

cephalothorax, which, in the Solpugidæ—the most Spider-like of the preceding families—is divided into four distinct rings, is here once more united into a single mass without segmentation; the abdomen, which also shows no division into segments, is attached to the back of the cephalothorax by a more or less slender peduncle; the cephalothorax has four pairs of limbs; and the antennæ are represented by a pair of falces (chelicerae), which perform the part of mandibles, and have a movable, claw-like, terminal joint. The respiration is performed by both lung-sacs and tracheæ.

The cephalothorax in these animals is covered above by a more or less horny plate, towards the front margin of which a group of simple eyes is situated. These are generally eight in number, but sometimes only six, or even less, and their relative position is of considerable importance in the determination of species and genera. The falces, which spring from the front of the cephalothorax above the mouth, are generally bent down vertically, but sometimes project more or less forward. Each of them consists of two joints, of which the basal one is large and stout, and furrowed along the inner margin, while the second is claw-like, sharp, and articulated to the apex of the first in such a manner that it can be folded back into the groove of the latter, and when erected it forms a biting organ more or less opposed to that of the opposite side. These may, in fact, be regarded as the jaws of the Spider, and they are rendered formidable weapons by the circumstance that they are perforated, and the canals passing through them to the apex of the claw-joint receive the ducts coming from a pair of poison glands, consisting of blind sacs, which extend more or less into the cephalothorax. The fluid secreted by these glands is poured into the wounds inflicted by the claws of the falces, and its effect upon the animal attacked is very marked.

As in the Arachnida generally, no mandibles are to be recognised, but the maxillæ are plainly developed, and bear a pair of palpi consisting of several joints. In the females these are simple organs like the legs, but shorter, and furnished with a claw at the end; in the males the last joint is inflated and excavated, and usually furnished with peculiar appendages which are employed in the transfer of the fertilising elements to the reproductive organs of the female. The labium, or part of it, would appear to be represented by a small piece projecting forward between the bases of the maxillæ, which is either joined to or separate from the sternal plate occupying the lower surface of the cephalothorax, from the edges of which the limbs take their origin, the first pair, which, as we have already seen, may be regarded as representing a second pair of palpi, as well as the rest. The legs consist of the usual number of pieces—a large coxa, a small trochanter, and a well-developed femur, followed by a tibia of two pieces, and a tarsus also usually of two joints. At the extremity of the tarsus are two claws, often associated with other organs which may be noticed under the families. The abdomen is generally covered with a soft skin, and except in a few instances shows no indications of its being originally composed of segments; near the apex on the under side it bears two or three pairs of spinnerets, to which we shall have to refer by-and-by.

In their internal anatomy the Spiders conform to the type already described (pp. 158, 159), but show certain special peculiarities. Thus the œsophagus has horny walls and terminates in a muscular dilatation, attached by a strong muscle to the back of the cephalothorax—an arrangement which renders it an efficient suctorial apparatus. The stomach is furnished on each side with five blind tubular extensions, which run towards and usually penetrate more or less into the palpi and legs; and the intestine continues tubular to near the extremity of the body, before reaching which it is dilated into a somewhat globular rectum. All these parts are kept in place by the voluminous lobes of the liver, among which the numerous branches of the Malpighian vessels are seen; these combine to form a pair of ducts which open into the dilated rectum. The organs of circulation consists of a chambered heart or dorsal vessel situated in the abdomen, from which heart numerous arteries are given off, while it is continued forward as an aorta into the cephalothorax. This divides



LYCOSA ANDRENVIVORA.

A, under surface of female: an, falces or chelicerae; p, maxillary palpus; c, coxa; st, sternum; sp, spinnerets. B, maxillary palpus of male, much enlarged.

after a time into two main branches, and sends forth a great number of arteries to the organs of the cephalothorax and the limbs. Respiration is effected, as already mentioned, partly by lung-sacs and partly by tracheæ. The former, of which there are one or two pairs, are situated in the basal part of the abdomen, where they open by slit-like stigmata protected by small special plates (*opercula*). Their structure and mode of action are the same as already described in the Scorpion. The tracheæ consist of two main stems, with more or less numerous branches, sometimes possessing more or less distinct internal fibres, sometimes partially or wholly destitute of anything of the kind. The main stems open to the air by a pair of stigmata situated in the lower surface of the abdomen, sometimes close to those of the lung-sacs, sometimes at the extremity of the body. The aperture of the generative organs is placed in both sexes at the base of the abdomen, between the stigmatic openings. The central nervous system is much more concentrated than in the Arthrogastra, consisting only of a central or supraœsophageal ganglion and a great nervous mass behind the œsophagus, the latter showing on each side four projecting portions, from which the nerves of the limbs are given off.

Besides these internal organs, the Spiders universally possess a set of glands for the production of a viscous fluid which has the property of hardening upon exposure to the air, and forms the silky threads which play so important a part in the lives of these animals. These silk-producing glands are exceedingly numerous, and pour out their secretion through a multitude of minute tubes situated on the lower surface of a set of peculiar organs known as spinnerets, placed near the extremity of the lower surface of the abdomen. There are from two to four pairs of these organs, which are sometimes quite short and nipple-like, placed close together in a little bunch, while sometimes one or two pairs are more elongated, and even divided into joints. In the latter case it is only the apical joint that bears the spinning tubes or "spinnerules" on its lower surface. The latter consist of microscopic horny tubes, through the minute apertures at the extremity of which the silky secretion escapes in threads of extreme fineness, a number of which unite before their consolidation to form the threads with which we are familiar. The production of these silky threads is, indeed, the most striking characteristic of the Araneida, and it enters more or less importantly into all their habits of life. By means of it they construct their dwellings, and some of them make most ingenious nets for the capture of prey; they make use of it continually when prowling about, as a safeguard against falling; they employ it in the construction of bridges, to cross from one elevated situation to another, and even as a means of aerial transport. The two last-named uses of the silky material require a few words of explanation here, as they are common to Spiders of several families. For the formation of a bridge from one tree, or other elevated object, to another, the Spider places itself on the summit of its resting-place with its front to the wind, and clings firmly to its support, usually with the aid of a few short threads stretched transversely to the direction in which it is looking. It then attaches a thread to the surface on which it is standing, and elevates the extremity of its abdomen as much as is possible. The wind immediately catches the short thread thus produced and exposed to its action, and draws it out continually, forming a loop of gradually increasing length, which floats away until it comes into contact with some solid body, to which it clings. The Spider has then only to draw the line tight and fasten it, and his communication with the distant point is complete. The same process is adopted with a view to an aerial excursion, a mode of diversion to which young Spiders of several families are very much addicted especially in the fine days of autumn. In this case, however, when the Spider feels that the quantity of silk that it has produced is sufficient to enable the aerial currents to bear it up into the air, it cuts away the original attachment of the thread and allows itself to be carried off.* Sometimes these flying threads are excessively numerous, and on their descent cover everything; they are particularly striking on hedges, and constitute, at all events, one of the causes of the phenomenon well known in the country as "gossamer."

The Spiders are all oviparous, and it would appear that the female, when once impregnated, produces several batches of eggs at considerable intervals of time. The number of eggs produced at once varies, but they generally form a considerable mass, enclosed by the female in a silken bag, which she sometimes carries about with her, sometimes conceals in her nest, and sometimes attaches to

* According to many writers no preliminary attachment of the thread takes place, but the Spider simply emits some fluid from the spinnerets, and allows the air to carry it away.

stones, plants, and other objects. The young resemble their parents in general form and structure, and undergo no metamorphosis.

In their habits the Spiders are all predaceous, and their prey consists almost entirely of small Arthropods, especially insects. In the capture of these they adopt various devices: some of them creeping about among plants and such objects until they find themselves within reach of a desirable booty, or lurking in dark corners to rush out upon any passing victim, others directly pursuing the fly or other insect that they have selected with a genuine cat-like stealthiness, while others weave most beautiful and ingenious snares for the capture of their prey. In all cases, however, the fate of the victim is the same; the Spider buries the claw-joints of its falces in the body of its prey, the juices and softer parts of which are then sucked out by the action of the muscular apparatus appended to the œsophagus.

Of this order several thousand species are known from all parts of the earth, but they are nearly all of small or moderate size, with the exception of a few tropical members of certain families which attain comparatively gigantic dimensions. In general the species inhabiting warm countries have little advantage in point of size over their relatives in temperate climates. The species are, however, more common in warm regions.

Fossil Spiders are not numerous, especially in the older rocks. Nevertheless, species occur in the Lithographic Slates of Solenhofen, and, as in the case of the Scorpions, one or two have been recorded from the Coal Measures of Silesia and Bohemia. They are more numerous in the Tertiary insect-beds, and a great many have been preserved in amber.

In the classification of the great number of Spiders forming this order there is not unnaturally some little difficulty, and the consequence is that nearly every original author adopts a method of his own, the results of which, as regards the bringing together of the different forms, are often very divergent. The following division into families, which is a slight modification of Gerstæcker's arrangement, will serve, we think, to give the reader a good general idea of the mutual relations of the different types:—

I.—Two pairs of lung-sacs and two pairs of spinnerets; claws of falces bending downwards	Tribe I.—TETRAPNEUMONES
One family	Family 1.—MYGALIDÆ.
II.—One pair of lung-sacs; usually six or eight spinnerets; claws of falces bending inwards	Tribe II.—DIPNEUMONES.
A. <i>Vagabundæ</i> . Ocelli usually in three rows; wanderers which spin no webs:—	
* Cephalothorax nearly rectangular	Family 2.—SALTICIDÆ.
† Cephalothorax narrowed in front	Family 3.—LYCOSIDÆ.
B. <i>Sedentariæ</i> . Ocelli in two rows; makers of webs for the capture of prey:—	
* Abdomen broad and depressed	Family 4.—THOMISIDÆ.
† Abdomen moderate, or, if broad, very convex:—	
a. Intermediate pairs of legs shorter than the others; webs more or less tubular	Family 5.—TEGENARIIDÆ.
b. First pair of legs usually the longest; webs irregular	Family 6.—THERIDIIDÆ.
c. First and second pairs of legs longer than the others; webs with more or less regular radiating and concentric lines	Family 7.—EPEIRIDÆ.

TRIBE I.—TETRAPNEUMONES.

FAMILY I.—MYGALIDÆ.

The group of the Tetrapneumones, or Four-lunged Spiders, which includes only the single family of the Mygalidæ, is distinguished not only by the presence of four stigmatic openings towards the base of the abdomen, but also by the possession of only four spinnerets, two of which are very small, and by having the claw of the falces bent downwards, so that those organs are kneed. This family includes a number of species, for the most part of large or considerable size, and some of them among the very largest of Spiders. They are mostly confined to the warmer parts of the world, only a few, and those comparatively small, extending their range into southern Europe, while a single species alone is recorded as an inhabitant of Britain.

The gigantic species of the typical genus *Mygale*, in which the body is covered with a rough, hairy coat, and the legs are also stout and hairy, chiefly inhabit the warmer parts of America and the West Indian Islands, although several species of them, and some of them of large size, are found in the Eastern Hemisphere. So far as the observations of naturalists at present go, most of them, at any rate, do not burrow in the ground, but reside in the grooves and fissures of the bark of trees, in the crevices between stones, and in other sheltered places, where they commonly spin a more or less tubular silken dwelling of suitable size, within which also the female deposits her eggs, enclosed in a regular case of white silk, to the number, according to some observers, of 1,800 or 2,000. The Spiders usually go in pursuit of their prey in the evening and during the darkness of the night, when they seize upon and destroy all the insects and other Arthropods that they are able to surprise and overcome, whilst, according to stories which have come down to us from a tolerably distant past, they are not content with insects alone, but even prey upon small birds and other Vertebrates. It would appear, indeed, from an observation of Mr. Bates, that there is some truth in their possession of these bird-catching propensities, in allusion to which Linnæus gave one of the large Surinam species described and figured by Madame Merian the specific name *avicularia*. Mr. Bates on one occasion found two small birds hanging in a torn web which was stretched across a cleft in a tree. One of them was already dead; the other, upon the body of which the Spider was resting, was at the point of death, and died soon after his taking it in his hands. He found that the observation of this habit of the Spider was quite new to the natives on the banks of the Amazon, and thus some doubt still remained as to its powers of bird-catching, and we believe that the gigantic Spiders which have been brought to the London Zoological Gardens from South America have not been experimented upon with birds; but Mr. Bartlett said that one of them attacked and killed a mouse. At the same time, it is very curious that the formidable falces of the large Mygalide are regarded with so little dread by the Indian children in the Amazonian region, that Mr. Bates actually found the latter on one occasion leading about one of these monsters by a thread put round his middle. The specimens that have been kept in the Regent's Park were fed chiefly upon Cockroaches and Meal Worms; one that was kept some years ago in Danzig killed and devoured some young frogs and other Amphibians. Several of the species exceed two inches and a half long, and their legs cover a surface of five or six inches in diameter.

A considerable number of species of rather smaller size than the above, and chiefly inhabiting the Old World, live in burrows which they excavate in the ground and line with a tube of silk. They generally close their habitations with a regular, closely-fitting door, attached to one side of the aperture by a silken hinge, and, from this peculiar construction of their domicile, they are known commonly as "Trap-door Spiders." The trap-door is composed of earthy particles firmly held together with layers of silk, and, although sometimes it consists of a mere flap falling down over the aperture, it is, in most cases, a regular stopper, accurately fitting into the orifice of the burrow. In some instances the Spider shows still more ingenuity in fitting up its abode as a place of refuge. After making the main nest, it works through at one side, and there digs both upwards and downwards obliquely, so as to produce a side chamber into which it can retreat should some enemy succeed in opening the trap-door; and the lateral chamber is cut off from the main burrow by a silky curtain-like door, which hangs before it, and thus apparently completes the inner lining of the tube. *Cteniza fodiens*, figured, with its nest, of the natural size, in our Plate 65, is a well-known South European species, especially abundant in Corsica. These Spiders issue from their nests at night in search of prey, and, after they have retreated into their fortresses, they will resist the opening of their trap-doors by clinging to the lining of the tube and to the inner coat of silk composing the doors. The females deposit their eggs in a silken cocoon at the bottom of their nest, and are said by some naturalists to carry their young about with them for a time after they are hatched.

Some of the species, including the single British type of the group (*Atypus sulzeri*), construct a somewhat different kind of nest. *Atypus sulzeri*, a Spider nearly half an inch long, with a large cephalothorax and enormous projecting falces, is found in several parts of England, principally in the south, and excavates as its dwelling-place a more or less cylindrical gallery, almost half an inch in diameter, in moist ground, the direction of which is usually at first horizontal and then vertical for a greater or less part of its length. The interior of this domicile the Spider lines with a compact tube



CTENIZA FODIENS AND ITS NEST.

of silk ; but instead of closing its aperture with a trap-door, the nest is finished by continuing the lining-tube beyond its mouth for a greater or less distance, the part thus left free lying upon the surface of the ground. The female deposits her eggs, which number from thirty to forty, in a silken cocoon, which she attaches to the inner extremity of her nest.

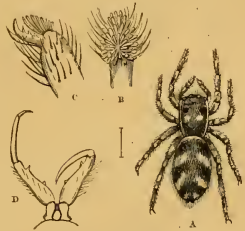
TRIBE II.—DIPNEUMONES.

The Dipneumones, as indicated by their name, possess only a single pair of lung-sacs, and the base of the under surface of the abdomen shows only a single pair of the opercula closing their apertures. The tracheal system has its apertures either immediately behind those of the lung-sacs or near the end of the abdomen. These Spiders, however, have another distinctive character in their falcæ, which may be placed either vertically or in an inclined plane, but always have the claw-joints articulated so that they bend in towards the middle line of the body.

FAMILY II.—SALTICIDÆ, OR SALTIGRADÆ.

The first two families of this tribe have the eyes nearly always placed in three transverse rows upon the surface of the cephalothorax. That is to say, we may distinguish two rows of two each and a third containing four, although in many cases an imaginary line may be recognised as combining the two separated pairs into a single curved row. In the Salticidæ the general form is compact, and the cephalothorax of nearly equal width from back to front, so that its shape is more or less rectangular. The legs are comparatively short and stout, and usually terminated by a pair of claws, below which there is a bunch of hair-like papillæ, termed a *scopula*, although sometimes this organ is wanting, and there are three claws. The extremity of the abdomen has three pairs of spinnerets.

The Salticidæ are generally neat and active-looking Spiders, of small or moderate size. The species are exceedingly numerous, and distributed in all parts of the world. Those of warm climates include the largest forms, and many of them display a remarkable brilliancy or iridescence of colouring. They are of wandering habits, preparing no snares for the capture of the flies and other insects on which they feed, but prowling about in search of their prey with a most extraordinary cat-like stealthiness, and often capturing it by means of a sudden spring. Their habit of making little jumps under such circumstances, and even when merely alarmed, has caused the family to receive the name of Saltigradæ, and is also alluded to in the name of the typical genus *Salticus*, upon which the family name Salticidæ is founded. They are to be found upon the trunks and leaves of trees and bushes, on railings, and about rocks and walls, in fact, wherever the flies which constitute their principal nourishment are to be met with. At the approach of danger they take shelter in holes and crevices, or throw themselves off and drop to the ground at the extremity of a fine silk thread, which it will be found they drag behind them, and attach from point to point all the while they are engaged in their predatory wanderings. This habit may be easily observed during the summer in the case of the commonest of the British species (*Salticus scenicus*), which may be met with almost everywhere in abundance, running about in the hot sunshine upon brick walls, palings, and the trunks of trees, and even upon the iron railings of balconies and other parts of houses in London itself. This interesting little creature, which is about a quarter of an inch long, and black, with white interrupted transverse bands, has a singularly alert look when engaged in its search for prey. Nevertheless, it moves everywhere with the greatest circumspection, and occasionally, by straightening the fore legs, elevates the front of the cephalothorax, in which we find a pair of enormous eyes, so as to obtain a wider range of vision. Its progress upon smooth and perpendicular surfaces is facilitated by the scopulæ, or tufts of adhesive hair-like papillæ placed at the extremity of each foot ; and when by this cautious method of approach the Spider has arrived near enough to its intended victim, by a sudden rush and spring the latter is at once seized and soon destroyed. Upon thin iron railings we have seen this Spider advance along the lower surface of the



SALTICUS SCENICUS.

A, female, enlarged ; B, foot from below with scopulæ ; C, foot from the side ; D, falcæ of male.

rail towards a fly sitting unsuspectingly on its upper surface, and peeping up from time to time to see whether it was yet near enough for the final spring, the whole behaviour of the creature reminding one forcibly of the conduct of a cat similarly occupied in pursuit of a mouse or bird. In June, the female constructs one or two cocoons of white silk, containing as many as fifteen or sixteen eggs, which are not agglutinated together. These cocoons, which are of a slight texture, are then enclosed in a compact cell made of white silk in the crevices of rocks, walls, and the bark of trees.

FAMILY III.—LYCOSIDÆ, OR WOLF SPIDERS.

The Lycosidæ, Wolf Spiders, or Citigradæ, like the preceding, are wandering predaceous Spiders, but they run down their prey without springing upon it after the fashion of the Salticidæ. Their ocelli are generally placed in three rows, and the cephalothorax is robust, but this part of the body is narrowed towards the front; the falcæ are placed vertically; there are three pairs of spinnerets; and the legs taper to the extremity, and are usually terminated by three claws, without any scopulæ or adhesive hairs, although some species have only a pair of claws, assisted by a small scopula at the end of each tarsus. Although inferior in size to the Mygalidæ, they are generally larger than the Salticidæ, and many of the tropical, and especially American species, exceed an inch in length of body. They take up their abode under stones, in the crevices of rocks and of the ground, in moss and under fallen leaves, and wander about, especially at night, in pursuit of the insects which constitute their chief food, and which they capture principally upon herbage and low bushes. Many of the species live among woods and on dry commons, but some seem to show a preference for marshy places and the neighbourhood of water, often even running upon the surface of pools, and making their way below the surface by crawling down the stems of aquatic plants. They can remain thus submerged so long as the air confined among the hairs covering the body will serve them for the



DOLOMEDES MIRABILIS.
Female, with egg-bag, enlarged.

purpose of respiration. While running on the surface of the water these Spiders freely seize the insects that come in their way, and one British species has received the name of *Lycosa piratica*, from its having this habit, which, however, is common to many others, and to some species of the allied genus *Dolomedes*, such as *D. fimbriatus*, a large and handsome Spider, attaining a length of five-sixths of an inch, that abounds in the fen country.

Notwithstanding their well-earned character for ferocity, these, like most Spiders, show a most affectionate care for their offspring. The *Lycosæ*, and some others, place their eggs, from the number of fifty to over one hundred, in a small, flattened, silken case, resembling two saucers put together by their edges, which they then attach to the under side of the extremity of the abdomen, and carry about with them. The female of *Dolomedes* places a still larger number (from two hundred to two hundred and fifty) in a rough-looking, globular cocoon, which she also carries about, holding it under her sternum by means of the falcæ and palpi, but at the same time attaching it to the spinnerets by a couple of strong threads. When the young Spiders are about to be hatched, the mother spins a dome-shaped web among low herbage, and under this the newly-hatched young cluster together on lines which they spin for their own accommodation, and remain there, carefully tended by their parent, until they have become able to shift for themselves. The most celebrated species of the family is the Tarantula (*Lycosa tarantula*), varieties of which, or of distinct, but very nearly allied species, occur throughout southern Europe. In some parts, notably in Italy, the bite of these large Spiders, which exceed an inch in length, is supposed to produce most remarkable effects, including a sort of epidemic dancing madness; but it would appear that, although their bite may give rise to disagreeable symptoms, the stories told by the older writers are much exaggerated.

FAMILY IV.—THOMISIDÆ, OR CRAB SPIDERS.

The Thomisidæ constitute the first family in which the eyes are placed in two rows upon the surface of the cephalothorax, and these rows are generally curved, sometimes in parallel lines, the first row sometimes more convex. The first two pairs of legs are generally longer and stouter than

the rest, and in the typical portion of the family the front pair are pushed forward quite to the fore part of the cephalothorax, and the whole body shows a generally broad and depressed form. They usually possess only two claws on each foot, associated with a few adhesive hairs, which sometimes form a small scopula. The peculiar short-bodied form and large arms of these Spiders have led to their being called "Crab Spiders." The name of *Laterigrade*, also given to the family by some writers, alludes to their frequently running sideways, like Crabs, a movement which is facilitated by the great development of the first two pairs of limbs.

The species of *Thomisidæ* are exceedingly numerous and very widely distributed, but they seldom run to a large size. Among the British forms a length of a quarter of an inch is considerable, but the American species are as a rule larger. The finest British species (*Sparassus smaragdulus*) is half an inch long in the female sex, which is of a fine green colour. The male is also green, but banded longitudinally on the back of the abdomen with crimson and yellow. They usually conceal themselves among herbage and in flowers, but sometimes in cracks and crevices of trees, rocks, and walls, or even in cracks in the ground and under stones. It is in these situations that they lie in wait for the insects which constitute their prey, which they sometimes seize by surprise on their coming close to the lurking-place, especially in the case of the flower-haunting species, and sometimes pursue with great agility. The females deposit their eggs, which vary in number from about thirty to two hundred or more, in a small compact cocoon of silk, usually of a lenticular form, like those of the *Lycosa*. These are sometimes, but rarely, attached to the lower surface of rocks and stones; generally the leaves of plants are selected for their reception, and these are either drawn together or bent at the edges, so as to form a protective covering for the cocoons. When alarmed, the Spiders of this family often adopt the crab-like device of simulating death to elude danger, and in this helpless attitude the species here figured may often be detected lying in the hearts of flowers, where its yellowish coloration renders it very inconspicuous. The young Spiders of this family are among those most addicted to float through the air on a support of gossamer in fine autumn evenings.



THOMISUS CITREUS.



DRASSUS CUPREUS.

FAMILY V.—TEGENARIIDÆ, OR TUBITELÆ.

In this extensive and varied family, of which the common House Spider may be taken as a typical example, we again find the eyes placed in two rows, but they vary somewhat in arrangement. The first and fourth pairs of legs are longer than the second and third, and all the legs taper towards the extremity, where they are generally terminated by a pair of claws, accompanied by papilliform hairs, which sometimes form a small scopula. In some cases there are three claws. All the Spiders of this family weave a more or less complete web for themselves, usually consisting of numerous threads sometimes united into a sort of sheet, but nearly always connected with a more or less tubular portion which serves as a dwelling-place and shelter for the Spider.

The *DRASSIDÆ*, a series generally of small Spiders of compact form and active habits, have three pairs of spinners, and generally only two claws on the tarsi, supplemented by numerous papillary hairs, which sometimes form scopulae. They are numerous in most parts of the world, and reside in silken cells which they build for themselves in the crevices of rocks and walls, among leaves, and under the loose bark of trees. In similar situations, or

attached to stones, the female deposits her eggs, to the number of forty, fifty, or more, in a firm and compact cocoon of white silk, about which, or within a light outer web surrounding it, the parent Spider remains in attendance on her progeny. This is especially remarkable in the case of some species which bury their cocoons in the earth, and these, as well as the species frequenting leaves, herbage, &c., often enclose the cocoon in a looser silken web, which serves the female as a habitation. The most remarkable of all the species, however, is the WATER SPIDER (*Argyroneta aquatica*), which passes the greater part of its life beneath the surface of the water, pursues its prey and even constructs its nest in this abnormal situation for an air-breathing Arthropod. The Water Spider is about half an inch long, and what is a remarkable circumstance the male is larger than the female. The cephalothorax and limbs are of a dark reddish-brown colour, and the abdomen, which is ovate, olive-brown. When swimming under water the numerous hairs with which the latter part is clothed carry down a supply of air in their interstices, and it is by means of this that the Spider is enabled to breathe. This air gives it a silvery appearance when swimming. Not content with this arrangement, which necessitates constant visits to the surface for fresh supplies of air, the Water Spider builds itself a dome-shaped cell, attached by silken threads to neighbouring objects in the water, such as sticks and plants, then by fetching down from the surface continual supplies of air and discharging them beneath the dome-like web, the latter gets inflated with air after the fashion of a diving-bell, and the little architect has a safe and comfortable dwelling in which it can rest freely for a longer or shorter time. The Spider appears to hibernate in its subaqueous dwelling, and also to deposit its cocoon of eggs there.

The DYSDERIDES are nearly related to the preceding, but have only six eyes, and a curious West Indian genus belonging to the group (the genus *Nops*) has only a single pair of rather large eyes placed far from the front margin of the cephalothorax. They are rather elongated, but strong and active Spiders, usually with large and powerful falcies, and reside in cells and tubes of silk placed under stones and in crevices of rocks, walls, and the bark of trees. From these habitations they rush out upon passing insects, which they take by surprise. The species are not very numerous, but are widely distributed. Several are recorded as inhabitants of Britain.

The SCYTODIDES, which also have six eyes, have a rather shorter and rounder body, and proportionately longer legs than the Dysderidae. They inhabit temperate and warm countries, chiefly in the Old World, and they are found in caves and houses, as well as under stones and among herbage. Their spinning is generally feeble, and they produce only a few irregular lines.

The CINIFLONIDES are a small sub-family, the known species of which are inhabitants chiefly of Europe, North America, and South America, but are represented also in the Atlantic islands. Mr. Blackwall distinguishes them by the possession of eight spinnerets, the fourth pair being placed quite at the base of the spinner, and consisting of a couple of very short, truncated, conical bodies of oval section, united to each other for their whole length. They are further characterised by having a peculiar organ, called a *calamistrum*, upon the first tarsal joint of each posterior leg. This consists of two close, parallel rows of short, movable spines, which are employed by the



ARGYRONETA AQUATICA.

Spiders in the construction of their very singular snares. These Spiders live in the crevices of rocks, walls, and the bark of trees, and among the leaves of trees and plants, and, in the neighbourhood of the places of their abode, they prepare their curious toils, composed of silk combed by the calamistra

into a dirty and shabby-looking material, curled and twisted into the semblance of an exceedingly loose, irregular, open network of extremely fine threads, usually supported upon a straight line of greater strength. This fine, loose material clings with remarkable tenacity to whatever it touches. The eggs of *Ciniflo atrox*, a common British species, are placed, to the number of about seventy, in a loose white silk cocoon of plano-convex figure, which is attached to the inner surface of an oval cell, composed of curled silk, disfigured on the outside by fragments of dirt of various kinds. The species of *Ergatis*, two or three of which occur in Britain, live generally upon heath and furze, the extremities of the twigs of which they surround with a loose, whitish web serving for the capture of their small prey, while, at the proper time, the female conceals within this web, upon which the remains of her victims are hanging, two or three lenticular cocoons, with from ten to thirty eggs in each.

The Common House Spider, and some allied forms, constitute the last sub-family of this group, that of the AGELENIDES, which are generally rather large, powerful Spiders, with the legs and usually the hindmost spinnerets long, and the eyes nearly always in two curved rows with the concavity forward. Under the common name of the House Spider are apparently included at least two species, *Tegenaria domestica* and *T. civilis*, the former rather more and the latter less than half an inch in length of body. There is considerable resemblance between them, but the legs of *T. domestica* are a good deal longer in proportion than those of *T. civilis*. With regard to the latter species, it has been ascertained that both sexes change their skin nine times, once within the cocoon and eight times after quitting it; that they live for four years, and the female after a single impregnation can produce nine batches of prolific eggs; and that limbs removed at the coxa will be reproduced six times at the succeeding changes of skin. The habits of the two species are very similar. They inhabit old neglected buildings, outhouses, &c., taking up their abode in the corners formed by walls, roofs, and rafters, where they spin a more or less horizontal sheet of web, from which many fine lines are given off to adjacent objects both above and below, while, in the most sheltered part of the corner, it communicates with a short tubular cell in which the Spider resides. The eggs are deposited in lenticular cocoons of white silk, each again enclosed in a silken bag, the outer surface of which is disguised by morsels of plaster and other rubbish.

The species of *Agelena*, several of which are found in Britain, live out of doors in woods and heaths, but they also produce a sheet-like web, furnished with a cylindrical tube for the Spider's dwelling-place. The commonest species (*Agelena labyrinthica*) is found generally upon heaths and waste ground, where its large cobwebs are often striking objects upon the heath and furze. The cocoons of the female are lenticular, contain from 50 to 120 eggs, and measure nearly half an inch in diameter; there are usually two of them, and these are enclosed in a large sac of compact white silk, to the interior of which the cocoons are attached by silken lines so compacted together as to have been compared to short pillars. The cocoons or their containing sac are often disguised with dirt, as in the case of the House Spider.

FAMILY VI.—THERIDIIDÆ.

This is a very extensive family of Spiders, usually of small or moderate size, having the abdomen generally large in proportion to the cephalothorax, and of a broadly ovate form, especially in the females, and the fore legs usually the longest of all. The eyes are arranged in two transverse rows, but sometimes in part elevated upon tubercles or other processes of the upper surface of the cephalothorax, and the tarsi have three claws at their extremity, frequently associated with others of very minute size. The species of this family are most numerous in temperate climates, and the greater number of the known forms belong to the Eastern Hemisphere. Many of them are adorned with elegant patterns, and display considerable variety of coloration. They inhabit the foliage of trees and shrubs, herbage, clefts and cavities in rocks and walls, and the interior of buildings, and are sometimes to be found under stones on the surface of the ground. In the more exposed situations they generally construct irregular snares, composed of fine threads crossing each other in all directions, whence the name *Inquietæ* has been applied to the family.

The females deposit their eggs in cocoons of various forms generally attached to some object



THERIDIUM NERVOSUM.

in the neighbourhood of the snare, or even within a slight protective web. Sometimes the cocoon, of a more or less globular form, is affixed to the under surface of the leaves of trees and shrubs, the edges of which are joined and more or less brought together by a loose tissue of silken threads, forming a sort of nest, in which the female may remain for a considerable time with her progeny after the latter are hatched, and actually supply them with food. *Theridion tepidariorum*, a species which has only been observed in Europe in conservatories, makes several pear-shaped cocoons, and suspends them by the narrow ends within a dome-shaped upper part of the snare; and the balloon-shaped cocoon of *Theridion variegatum*, as described by Mr. Blackwall, "is composed of soft silk, of a loose texture and pale brown colour, enclosed in an irregular network of coarse, dark red-brown filaments. Several of the lines composing this network unite near the smaller extremity of the cocoon, leaving intervals there through which the young pass when they quit it, and being cemented together throughout the remainder of their extent, form a slender stem, varying from one-tenth to half an inch in length, by which the cocoon is attached to the surface of stones and fragments of rock, resembling in figure and position some of the minute plants belonging to the class Cryptogamia." The cocoon itself is about an eighth of an inch in diameter. The curious species *Pholcus phalangioides*, which, although slender in its form, and endowed with limbs rivaling those of the Phalangiide in length, is nearly allied to the *Theridia*, forms a globular cocoon of slight texture, but of large size, which the female carries with her wherever she goes, holding it firmly by means of the palces.

The *Liopythia*, which seem to lead in some respects towards the next family, also construct a more regular snare than the typical *Theridia*. They make a fine sheet of web, stretched horizontally among the leaves and branches of trees and bushes, the herbage and other objects which form their ordinary shelter, and further held in position by fine intercrossing lines stretched from its surface to neighbouring points of support. These Spiders take their place to lie in wait for prey on the under surface of the web, and they immediately seize any insects which fall upon it; the intercrossing lines, especially those above the web, serving to check and throw down flying insects that may strike against them. Some species of the extensive genus *Neriene*, nearly all of which are very small, make snares similar to those of the *Liopythia*; others reside under stones. Many of them are noted as aeronautic species.

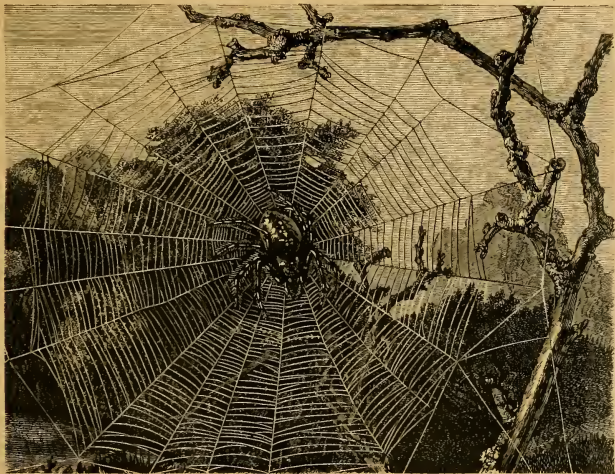
The species of the allied genus *Walckenaera* (or *Micryphantas*) frequently have the portion of the cephalothorax which bears the eyes more or less elevated or tubercular, and in *Walckenaera acuminata* this character attains an extreme development. In the female there is a truncated conical tubercle, having four eyes at its apex, and the other four in two pairs a little way down on the sides. In the male the eye-bearing process is of considerable length, upright and slender, terminating in a bilobed enlargement, each lobe of which bears two eyes, while the other eyes are placed in pairs upon the sides of a swelled portion about half-way down. This singular little Spider, which is about a sixth of an inch long, is found under stones and on rails in various parts of England. The species of *Pachygnatha* are remarkable for the enormous development of their palces, which are so large as to form a pair of stout divergent pieces at the front of the cephalothorax. *P. derckii* is a widely distributed British species, found under stones, &c.

Certain foreign species of this family share with the Tarantula in the evil reputation of being dangerously venomous creatures. They belong to the genus *Latrodectus*. The best-known species is the Malmignatte (*Latrodectus malmignattus*), which is almost half an inch long, and is common in the south of Europe and the islands of the Mediterranean, especially Corsica. It is a black Spider, adorned with about thirteen blood-red spots upon the abdomen. Its ordinary prey would appear to consist of rather large insects, such as Grasshoppers, which it is said to entangle and partially disable by means of threads stretched in various directions across the fields. Upon such insects the Spider inflicts a bite at the junction of the head and thorax, and the victim, if small, is said to die instantly, if large, to fall into convulsions, which, after a short time, terminate in death. The effect of the bite upon the human subject is also said to be very serious, as it causes much pain and fever, and, according to some writers, leads to fatal results. The same species, or a nearly allied one, occurs in Morocco, and is much dreaded. Its bite is also described as fatal; and two or three others are found in the Southern States of North America, of which similar tales are told. The female

Malmignatte is described as producing three large cocoons, each enclosed in a very compact and strong silken covering. They contain a diminishing number of eggs, the first produced having 400 and the last about 200.

FAMILY VII.—EPEIRIDÆ.

In this family we have to do with the most familiar of all Spiders, the Garden Spider, whose beautiful geometrical webs force themselves upon our attention in the autumn, and some allied species which chiefly inhabit the woods and hedgerows. All these Spiders have the first and second pairs of legs longer than the others, the tarsi terminated by three or more claws, with the additional



COMMON GARDEN SPIDER (*Epeira diadema*).

ones very minute, and the eyes placed in two rows, with the two intermediate pairs generally larger than the others and forming a square figure, while the lateral ones are placed close together in pairs. In the British and European forms the abdomen, especially in the females, is of large comparative size, rounded or ovate and very convex. They all produce the vertical circular webs above alluded to, and hence the family has been called OREITELE. The species are generally of considerable size, and some exotic forms measure over an inch and a half in length. They are very generally distributed over the face of the earth, and those of some tropical countries present very wide differences from the ordinary forms with which we are acquainted. They reside and construct their very ingenious snares chiefly among the branches and foliage of trees and bushes, but also frequent herbage, and sometimes avail themselves of the shelter of caves and buildings. The Spider resides and passes the winter in a dome-shaped silken cell formed in the neighbourhood of the snare, and usually connected directly with its centre by a strong line; and in similar cells the female encloses the cocoons containing her eggs, which are rather loosely constructed of silk, and of a globose or balloon-like shape. In some instances the Spider apparently encloses her whole stock of eggs in a single large cocoon. Thus Mr. Blackwall describes that of *Epeira quadrata*, a well-known and very fine British species, as containing from 900

to 1,000 eggs; and the still more familiar *E. diadema* of our gardens similarly places 700 or 800 eggs in a single cocoon: whilst other species, including the widely-spread *E. apoclista*, break up their store of eggs into detachments, and produce several cocoons, each containing about 200 eggs. The eggs are agglutinated together into a more or less lenticular mass, and the young Spiders, when first hatched, commonly spin a few lines, upon which they group themselves so as to form a compact little mulberry-like mass of living creatures, which disperse in the most extraordinary fashion if disturbed. The eggs in the cocoons are subject to the attacks of Ichneumons and other parasites.

The construction of the snares of the Common Garden Spider (*Epeira diadema*) must be familiar to everybody. They consist of a number of stout radiating lines running from a common centre to a set of strong lines stretched between various neighbouring points of attachment, and enclosing the space occupied by the snare, and crossed by a series of short lines, which, as a whole, constitute a spiral running from the centre to the outer margin of the actual snare. The Spider commences its operations by stretching the outermost or foundation lines, which are attached to accessible points and then carried to other points and there fixed, the Spider sometimes dropping to the ground and walking across to the base of the opposite point of attachment, sometimes emitting a thread from its spinners, and allowing it to be carried away by the wind until it attaches itself to some object, and thus forms a bridge. These foundation lines are made strong, and the radiating lines are tightly stretched between them, and all joined at the centre of the future snare, and all these parts consist of simple smooth silken threads. The Spider then starting from the centre proceeds to stretch a series of short threads between the radii, in doing which it follows an absolutely spiral course around the centre, so that the short cross-threads are really arranged spirally, although, of course, each inter-radial piece is straight. But the most remarkable point is that the whole of these inter-radial pieces of thread, except those forming a few turns close to the centre of the snare, are of a totally different structure from the rest of the net. They consist of a slender elastic silk thread, covered with little beads of a viscous substance, which, no doubt, give them a greatly increased power of adhesion to any unfortunate insect that may come in contact with them. The central part, from which the viscous beads are absent, is the station in which the Spider lies in wait for its prey, hanging head downwards. Its shelter, as already stated, is a silken cell usually attained by a special thread, but sometimes only by one of the radii. This whole snare, or, at all events, all the viscid lines of the spiral, are renewed daily, and notwithstanding its complication the Spider occupies only about an hour in its fabrication.

It will be easily understood that a delicate net of this character stretched vertically in the air will capture many flying insects, and the owner, seated comfortably in the centre, is at once aware, by the shock produced upon its network and the subsequent struggles of the insect, that a victim is caught, and will further be able to judge of its whereabouts. To satisfy doubts upon this latter point, or to make a struggling prey entangle itself more thoroughly, the Spider will often, under these circumstances, shake its web violently; but it usually soon makes its way to the spot and effectually secures its prisoner by turning it round and round by movements of the legs, and at the same time swathing it in an abundant supply of silk, poured forth from the spinnerets. In this operation many species are aided by peculiar spines (called *sustentacula*) attached to the last joints of the posterior legs, which move in such a manner as to form with the claws regular claspers capable of drawing out silk from the spinnerets, and of performing various other functions in connection with that secretion. Mr. Blackwall describes the process in *E. diadema* as follows:—"Causing the victim to rotate," he says, "by the action of the third pair of legs and the palpi, the first pair of legs being also frequently employed in a similar manner, they extend the spinners laterally, and applying to them alternately the *sustentaculum* of each posterior leg, they seize and draw out numerous fine lines in the form of a fillet, which they attach to their revolving prey, and thus involve it in a dense covering of silk from one extremity to the other. By means of this stratagem," he adds, "they are capable of overcoming formidable and powerful insects, such as Wasps, Bees, and even large Beetles." It must be remarked, however, that these Spiders do not like Wasps in their nets, and have even been known to cut them carefully out and drop them to the ground.

The British and European species of this family are usually of nearly the same general form. The females have a large ovate or globose abdomen, the basal part of which projects high over the

surface of the cephalothorax, while the males have the abdomen more elongated and less convex. The males also are smaller than the females, and have the first and second pairs of legs more elongated, and as the connubial relations of these, as of other Spiders, are by no means upon what we should regard as a satisfactory footing in human society, and the female is usually quite ready to kill and feed upon her suitors, the actions of the male, as he ventures upon the web on which the object of his attentions dwells, are exceedingly diverting. He advances slowly, apparently feeling his way with his long fore legs, and the least movement on the part of the lady generally causes him to retire for



GASTERACANTHA ARCUATA.

the moment. The number of species is very considerable, and many of them show very fine colours, or an elegant pattern in their arrangement. The only British species that presents a striking peculiarity of form is the *Tetragnatha extensa*, a rather long, narrow species, resembling the *Pachygnathæ* of the preceding family in having long, divergent palces, and further distinguished by its habit of extending the legs before and behind nearly in a line with the body. It is nearly half an inch long, and is found in damp localities.

In the tropical part of both hemispheres there are a considerable number of species of this family which present great differences from those best known to us, especially in having the abdomen of a more or less horny texture, and produced into spines or processes often of enormous size. They form the genus *Gasteracantha*, and allied genera, which are particularly well represented in Brazil and other parts of tropical America. In their habits they resemble the Garden Spiders, and, like them, they spin a geometrical web.

CHAPTER II.

ORDERS ACARINA, TARDIGRADA, LINGUATULINA, AND PANTOPODA.

ACARINA—The Mites and their Allies—Characters—Classification—BDELLIDÆ, OR BEAKED MITES—TRONBIDIIDÆ, OR HARVEST MITES—HYDRACHNIDÆ, OR WATER MITES—ORIBATIDÆ, OR BEETLE MITES—GAMASIDÆ—IXODIDÆ, OR TICKS—ACARIDÆ, OR TRUE MITES—TARDIGRADA—LINGUATULINA—PANTOPODA.

ORDER III.—ACARINA.

THE innumerable host of the Mites and their allies, presenting an almost infinite variety in their organisation, constitute the order Acarina, the last order of Arachnida in which any special respiratory organs are to be recognised. Their respiration is effected solely by tracheæ. Their leading

characteristic is the amalgamation of the abdomen, which shows no signs of segments, with the cephalothorax, to form a single mass. The second pair of maxillary palpi, developed into a leg-like form, act as legs, and are counted as the first of the four pairs of legs with which the normal adult Mite is furnished. The mouth is constructed either for biting or for sucking. But the reader will see, even from the few descriptions and figures of animals of this order that we can here offer to him, that it is almost impossible to draw up a character of this order which shall strictly include all its members.

As already stated, the segments of the body are fused into a single mass, whence the name Monomerosomata has been applied to the order. Only in a few species a transverse impressed line marks off the head, and, in a still smaller number, there is a similar indication of the hinder limit of the thorax. The chelicere, which represent the antennæ, are here, as in most of the preceding forms, the principal organs of the mouth. In the biting species they are permanently prominent, and terminated either by a claw or by a small nipper; in the suctorial forms, they acquire the form of hooks, needles, or minute saw-like organs, and are then protrusible from and retractile within a sort of sheath formed by the first pair of maxillæ, in conjunction with which they form a sucker. The palpi of the second maxillæ (labium) are, as already stated, developed into acting legs, and, including these, the mature Acarine has usually four pairs of limbs.

With regard to their internal structure, these animals are rather simple. The intestinal canal is short, running from the mouth to the anal opening, which, in most of them, is situated upon the lower surface, at some distance from the apex of the abdomen. In some cases it is almost a simple tube, but generally there is a more or less distinct stomachal part, from each side of which three blind tubes are given off. Except in the *Trombidia*, which have the intestine partly surrounded by a bunch of minute glandular bodies, there is no trace of the liver-like organ which attains such a development in the higher Arachnida; but the walls of the blind stomachal tubes are generally glandular, and may take the place of a liver.

As above stated, the Acarina are regarded as Arachnida with tracheal respiration, but in many, especially parasitic forms, no organs of respiration have yet been discovered, although from other characters presented by the creatures there can be no doubt that they are rightly placed in this present order. When respiratory organs have been detected they consist entirely of very delicate tracheæ, sometimes even destitute of the spiral thread which is characteristic of insect tracheæ, branching in a tuft from a main stem on each side. These main stems communicate with the stigmata, through which the air has access to the interior of the body, and these are generally only two in number, placed one on each side of the body, and situated either at the base of the chelicere or in one of the hinder pairs of legs. The circulation of the blood appears to take place in the body-spaces, and no dorsal vessel has yet been discovered. The central nervous system, as might be expected from the general structure of the body, is much concentrated, consisting, in fact, of a single great ganglionic mass, traversed by the œsophagus, and giving off nerves in all directions. The Acarina are of separate sexes, and the internal sexual organs are sometimes rather complex. They open in the ventral surface, often far forward. Nearly all lay eggs, but the species of the family Oribatidæ produce living young. In most cases the young quit the egg under a form more or less different from that of their parents, and in attaining to the latter many of them pass through transformations which may be regarded as, to some extent, analogous to those of insects. The main difference consists in the absence of one pair of legs, which does not make its appearance until after a change of skin, and frequently a resting or pupal stage, in which the immature animal is generally parasitic in its habits.

The Acarina, which are all of small size, and many of them of microscopic minuteness, are, as might be expected, of universal diffusion over the face of the globe, and their distribution in any given country is equally universal, while the functions they perform in nature fulfil nearly every office that creatures so small are capable of. Some inhabit the water, and even the sea has its Acarine inhabitants: others, the great majority, live on land or on plants of various kinds. Many are parasitic both upon and beneath the surface of other animals; others are predaceous, seizing and devouring such little creatures as they are able to overcome. Some again feed upon living vegetable matters, and many of these give rise to gall-like deformations of the parts of plants that they

attack; whilst others do not disdain dead, and even dried animal and vegetable materials, and thus act the beneficial part of scavengers. In a fossil state Acarina are known only as inclusions in amber.

The Acarina may be divided into seven great families, some of which, however, include a considerable variety of forms. The following tabular arrangement will serve as a guide to their general characters:—

- | | |
|--|----------------|
| I. Fore part of head prolonged into a distinct beak, and separated by a constriction from the rest of the body | 1.—BDELLIDÆ. |
| II.—Fore part of head not prolonged into a distinct beak. | |
| A. Skin firm. | |
| 1. Skin scarcely extensible; palpi not seated on a common chin-piece. | |
| a. Chelicere claw or needle-like. | |
| * Palpi terminated by a pair of nippers | 2.—TROMBIDIDÆ. |
| † Palpi with bristles or a hook at the extremity | 3.—HYDRACHIDÆ. |
| b. Chelicere with nippers. | |
| * First joint of palpi very large | 4.—ORIBATIDÆ. |
| † Joints of palpi nearly equal | 5.—GAMASIDÆ. |
| 2. Skin leathery, very extensible; palpi attached to a chin-plate | 6.—XODIDÆ. |
| B. Skin soft, with a few chitinous bands | 7.—ACARIDÆ. |

FAMILY I.—BDELLIDÆ, OR BEAKED MITES.

In these there appears to be a distinct head, separated by a constriction usually resembling a short neck from the rest of the body, but this projecting beak apparently consists only of the mouth, and the eyes, when present, are situated behind the constriction. The latter organs vary in number from two to six. The chelicere terminate in nippers; and the first pair of palpi are long and slender, composed of five joints, and generally more or less elbowed at the end of the second joint. These are small Mites, usually of a bright colour, slow in motion, and living in damp ground. The young resemble their parents. The best-known species is *Bdella longicornis*, which is about one twenty-fourth of an inch long, scarlet, with four eyes. These Mites appear to be predaceous in their habits.

FAMILY II.—TROMBIDIDÆ, OR HARVEST MITES.

This is a much more extensive family than the last, with which, however, it has much in common. Its members never display the separate head-like part characteristic of the Bdellidæ, and the first palpi are short and stout, but their termination shows two opposite pieces, one of which is a claw. The chelicere do not end in nippers; and the legs consist of six or seven joints, and are terminated by a pair of claws. These Mites are generally of some shade of red, often of the brightest vermilion, but sometimes more or less spotted with brown or black. They live upon the ground, and among plants, and many of them run very fast. The young are six-legged, but otherwise like their parents. Many of them pass through a parasitic stage.

A considerable number of these Mites are vegetable feeders, and some of them occasionally do a good deal of mischief to various plants and trees, of which they frequent the under sides of the leaves, pricking the tissues with their sharp chelicere, and sucking out the fluids. One of the commonest species is well known as the Red Spider (*Tetranychus telarius*), although it varies a good deal in colour, apparently with age; but the majority of the specimens are of a brick-red. It is found upon a great variety of plants and trees in our gardens, spinning an exceedingly delicate web, under which a whole colony of all ages lives in security. Other species of the genus *Tetranychus* and its allies also abound upon many cultivated and wild plants. The young form of one species, which appears to be a *Tetranychus*, is the well-known "Harvest Bug," which torments tender-skinned people so seriously if they wander in country places in the autumn. The Mite that penetrates the skin is the six-legged form, and has been described under the name of *Leptus autumnalis*. It attacks not only human beings, but dogs, cats, and many other animals. The best remedy for the itching it produces is to rub the part affected with some essential oil.

The Scarlet Mite (*Trombidium holosericeum*) may serve as the type of a large group of Mites belonging to this family, but of carnivorous habits. It is about a twelfth of an inch long, with

a squarish pear-shaped body, upon which two parts may be recognised, a small anterior and inferior portion bearing the eyes, the organs of the mouth, and the first two pairs of legs, and a larger posterior portion, on the under surface of which, at some distance from the others, the third and fourth pairs of legs are situated. The whole Mite is of a bright scarlet colour, and the larger hinder part shows a beautiful velvety texture. This Mite may be often seen running about upon the ground, in moss upon the roots of trees, &c. and it is exceedingly rapid in its movements. In a young stage, it passes a certain period as a parasite upon the long-legged Harvest Spiders (*Phalangium*), usually selecting the females, and attaching itself behind the hinder coxæ, where it is out of reach. In this situation it remains, although capable of some amount of movement, and its six legs advance more and more towards the front as the animal grows. When detached from the Harvest Spider, it conceals itself in the ground, and becomes an oval nymph, within the skin of which the eight-limbed perfect Mite may be watched in process of formation. The change takes about three weeks. Other species of the group attach themselves to insects of various kinds to undergo this nymphal change, and, as all of them attack and destroy Aphides, and other minute insects, they must be regarded to a certain extent as our friends.

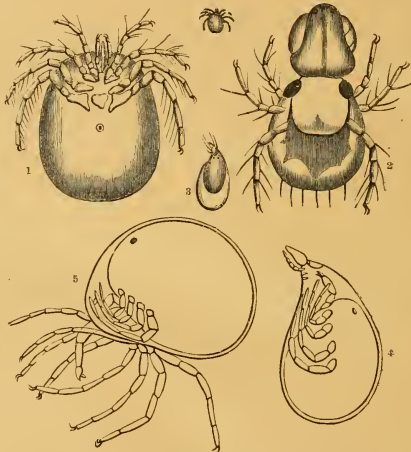


TROMBIDIUM
HOLOSERICEUM.

FAMILY III.—HYDRACHNIDÆ, OR WATER MITES.

These creatures may be regarded as aquatic representatives of the *Trombidia*, as they resemble these in many characters. They have usually a more globose form of body, and there is no trace of its division into two parts; the chelicere are similar; the palpi terminate in hooks or bristles; and the legs, which generally increase in length from the first to the fourth pair, are strong and fringed, and terminated by a pair of claws. They have two ocelli on the fore part of the body.

These Mites, which are generally of tolerable size for their order, a sixth of an inch being a common length, live habitually in water, many of them swimming with great ease and considerable rapidity, while some prefer crawling upon the bottom. Some of them even live in the sea. Although they remain constantly under water, and apparently never come to the surface to breathe, they possess no recognisable branchial organs, but are furnished with the usual tufts of tracheæ, opening by stigmata placed between the fore legs. Under these circumstances it is rather difficult to understand how they carry on their respiration, and some naturalists have suggested that their tracheæ must be enabled to respire the air dissolved in the surrounding water. Of this, however, there is, we believe, no evidence. The young differ very materially from their parents. Like other young Mites they have only three pairs of legs, but they are also provided at the fore part with an enormous suckorial organ, by means of which they attach themselves as external parasites to aquatic insects of all sorts.



THE METAMORPHOSES OF HYDRACHNA GLOBULUS.

1. The perfect mite, natural size and magnified; 2, the larva, magnified; 3, a nymphlet; 4, a nymph, magnified, showing the eight-legged mite within; 5, the last form of nymph, magnified.

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In this parasitic condition, deriving nourishment from the fluids of their hosts, they gradually increase in size, and at length, after a period of quiescence, undergo the change into the adult form within the skin which has covered them as larvæ. In this mature state they are generally handsome little creatures, glorying in bright colours, especially red, and frequently adorned with black or brown markings. As parasites they may be found commonly upon the larger Water Beetles, the Water Scorpion (*Nepa*), and especially the species of *Gerris* which run upon the surface of the water. Some species appear to become parasitic in Molluscs when adult, and one of these (*Hydrachna concharum*) has been supposed to cause the formation of pearls in fresh-water mussels by the irritation that it excites in the mantle.

One or two species which appear to belong to the present family have been found swimming in the sea, and form the genus *Pontarachna*. Examples have been met with on both sides of the Atlantic and in the Mediterranean. Besides these, several species of marine Mites of more doubtful relationships have been obtained on English and other coasts, partly by dredging and partly by the investigation of rock-pools on the shore, and these may be mentioned here, although most of them appear to be more allied to the following family. Special attention was first called to them by Mr. Gosse, who met with examples at Ilfracombe, and the late Mr. Andrew Murray was inclined to place them in a separate family, which he names HALACARIDÆ, from the name (*Halacarus*) given by Mr. Gosse to one of his genera. As general structural characters of his proposed family, Mr. Murray says that they have either a stiff or a more or less rigid cuirassed skin, and their legs springing from the outer margin of the body.

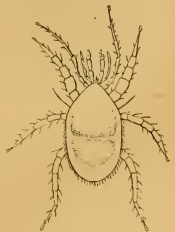
FAMILY IV.—ORIBATIDÆ, OR BEETLE MITES.

This family consists chiefly of ovate or globular Mites covered with a hard and shining skin, so hard and shining in many cases as to remind one of a Beetle. They have retractile pincer-like chelicere; and the first joint of their short four-jointed palpi large, and converted into a masticating organ. They have no eyes, and the tarsi are terminated either by one or three claws. These are all terrestrial Mites, generally of small size, although some of them attain the bulk of an ordinary pin's head. They appear to be vegetable feeders, although this is not quite certain, as they occur in moss and under the bark of trees, where minute animals abound; but some species have been observed to bore into rotten wood, and apparently feed upon it. Their colour is generally dark brown, or nearly black, and the cephalothorax is often dilated at the sides, and sometimes provided with a pair of cup-shaped stigmata. In the young state there would appear to be an approximation between these Mites and the Acaridæ, as Professor Claparède found associated with a black species (*Hoptophora contractilis*) a soft white Mite, like a Cheese Mite, and it seemed clear that this was a stage in the development of the black Oribatid.

FAMILY V.—GAMASIDÆ.

This family includes a great number of small, eyeless, horny-looking Mites, which may be found free upon the ground and in moss, but are more frequently parasitic in their habits, living especially upon the surface of terrestrial insects of various kinds. They have nipper-like chelicere, free, nearly equal-jointed palpi, and legs generally similar in size and form, covered with hairs, and terminated with a pair of claws and a large pad. The skin is sometimes firm throughout, sometimes only in parts, the rest being soft and flexible as in the Acaridæ.

Although parasitic in their mode of life, the Gamasidæ do not attach themselves to their victims by any permanent suctorial apparatus, but remain free and able to crawl about at pleasure, except that in one common species on Beetles, called *Uropoda vegetans*, the Mite fixes itself to the surface of its host by means of a sort of cori, the ends of which are attached to the Beetle and to the under surface of the Mite. This cord, which is neither horny nor tubular, would seem to be formed by the excrements of the Mite. A common and characteristic species is the *Gamasus coleoptatorum*, which also infests Beetles, and is one of those species in which part of the upper surface is not horny. The insects on



GAMASUS COLEOPTATORUM.

which they chiefly occur are such as burrow into the ground, in Britain especially the common Dung Beetles (*Geotrupes*) and the Humble Bees.

Besides these well-known parasites of insects, the family includes several species which infest vertebrate animals, and are sometimes great plagues. One of the best known is the "Tick" (*Dermangssus avium*) that infests domestic poultry, and also makes its way into pigeon-houses, and even into the aviaries and cages in which small birds are kept. When numerous, these parasites are often injurious and even destructive, especially when they attack small birds; and they will also transfer their operations to the bodies of human attendants on their natural victims, sometimes with very disagreeable results. Several other species of *Dermangssus* and allied genera live parasitically upon Bats, and some of these present most remarkable characters.

FAMILY VI.—IXODIDÆ, OR TICKS.

In the Ixodidæ we have another family of parasitic Mites, some of which are well known in Europe under the name of Ticks, although it is in warmer climates that they most abound and attain their largest size. Some of them are indeed the largest of the Acarina, reaching a length of a third of an inch or more. They are more or less ovate or sometimes nearly circular in form, covered with a leathery and very extensible skin, part of which may, however, be horny; the palpi are small, seated on a chin-plate; the chelicereæ are retractile and generally serrated; the eyes are sometimes present, sometimes wanting; and the legs are similar in form, with two claws and a pad.

The sucking apparatus of these parasites is composed of the maxillæ and the chelicereæ. The former combine to form a sort of ring-like lower lip, from which the ligular portion extends forward as a grooved piece, the convex surface of which is furnished with reversed hooklets. The chelicereæ work in the groove of this piece, and can be pushed forward and retracted by the action of strong muscles, so as to perform the part of piercing organs, while their serrated margins assist in holding the parasite firmly to its victim. The quantity of blood drawn by these little pests from their hosts is by no means commensurate with their original size. The skin is so extensible that in many instances the full parasite increases to many times its original bulk, and when the victim is attacked by many such enemies at once the consequences may be serious. Although generally confined to some particular species or group of animals, the Ticks occasionally get upon the bodies of men, and are then very troublesome. Two species of the genus *Argas* (placed by many authors with the preceding family)

are particularly noted as attacking mankind. One of these is the *Argas reflexus*, originally a parasite upon young pigeons; the other may be called the Persian Tick (*Argas persicus*), a species found in houses in some parts of Persia, and described as producing most serious effects upon those whom it attacks at night.



I

IXODES FLAVOMACULATUS.

Of the species of the genus *Ixodes* and the genera which have been separated from it, many inhabit woods, forests, hedge-banks, and herbage generally, and attach themselves to passing animals. Thus *Ixodes erinaceus*, a British species, is often found on dogs, foxes, hedgehogs, and cattle, and is known as the "Dog Tick;" another (*Ixodes marginatus*) is described as having swarmed in such great numbers in hay-fields as greatly to impede the operations of mowing and drying the grass. A few species are found on bats,

but of those which are confined to particular animals the majority, so far as known, are parasites of different kinds of reptiles, especially snakes. They generally attack these near the eye. The species figured is parasitic on a West African *Python*.

FAMILY VII.—ACARIDÆ, OR TRUE MITES.

This last group includes all the Mites that have not been cut off from the original family Acaridæ to form special families, and hence its members naturally show some little divergence of character. They are all minute and very lowly organised Arachnida, and their skin throughout is thin and membranous, with here and there a harder band for the support of the limbs. The chelicereæ are nipper-like, or pointed, and in the latter case capable of being retracted into a sheath; there are no eyes; and the legs are either mere stumps, or produced and terminated by an adhesive vesicle.

In their habits, as in their structure, they are most various. Thus a considerable number, of which the common CHEESE MITE (*Tyroglyphus domesticus*) may be taken as the type, live either in dry or decaying animal and vegetable materials, or upon the roots of plants, such as Liliacæ (between the scales), potatoes, dahlias, &c., or in Agarics. Cheese, flour, and sugar are also favourite substances with these little creatures. The members of the genus *Hypopus* and its allies, distinguished by having the two anterior pairs of feet fairly or well developed, while the two hinder pairs are small and concealed beneath the body, are found externally parasitic upon a variety of insects, and also occasionally upon vertebrate animals. *Hypoderas*, on the contrary, the species of which have a more or less elongated body, with two pairs of legs issuing from close to the anterior end, and two pairs from much farther back, includes internal parasites, some of them living under the skin, or in the muscles of various vertebrate animals, and others in their brouchial tubes and lungs, or in the air-cells which exist under the skin in many birds. Occasionally these minute parasites occur in immense numbers.



TYROGLYPHUS DOMESTICUS.

A very considerable number of species, belonging to the genus *Sarcoptes* and its allies, are parasitic in the skins of various vertebrates, upon which they cause the disease commonly known in man as "the itch." They are generally of a broadly ovate or rounded figure, with the skin more or less distinctly striated across, and furnished with the usual four pairs of legs, placed half towards the front and half towards the posterior part of the body, the legs generally having several bristles, and terminating in a slender tarsal part with a sucker at the end. The chelicere are nipper-like, and it is by the agency of these that the parasites burrow beneath the epidermis of the animals they infest. The species attacking human beings in Europe generally is the *Sarcoptes scabiei*; but in Iceland and the northern part of Europe another form is so common that in some localities scarcely any of the inhabitants seem able to escape from it, and this produces a much more formidable complaint than the common Itch-mites. When the disease is allowed to proceed unchecked the parts of the body attacked by it become coated with a sort of crust, which is said to consist of the dead *Sarcoptes*, massed together by some viscid fluid, thus often simulating elephantiasis. Allied forms attack the fox, dog, cat, goat, pig, rabbit, fowl, horse, ox, and other quadrupeds and birds. Besides, there

are a good many louse-like Mites, related to the preceding, which are found as surface parasites upon mice, bats, and birds, in various countries. These sometimes have the tarsi terminated by curved claws, which assist them in clinging to the hairs of their victims. Most of them have sucking mouths, but some appear to be organised for biting. In connection with these parasites we may mention the curious species *Demodex folliculorum*, a microscopic, worm-like creature, closely ringed throughout, furnished towards the anterior end with four pairs of very short limbs, each of which terminates in two claws. The mouth is suctorial. The larva has only three pairs of legs. This singular little parasite occurs pretty frequently in the hair-follicles and sebaceous glands of the skin in man, where it often gives rise to pimples, from which it may be squeezed by a careful application of the nails. It is, no doubt, the "maggot in cheese-monger's nose" commemorated by Butler in "Hudibras," though we are not aware that it bestows its visits especially upon any particular class of tradesmen. A very considerable number of species referred to this family, and chiefly to the genus *Phytoptus*, attack the living tissues of plants, co-operating with the Aphides in their attacks upon the leaves and other growing parts, and, like them, often causing the formation of peculiar gall-like deformities and excrescences. The Mites, like the Aphides, generally attack the under side of the leaves, and cause them to grow up into hollow excrescences of various forms, in the interior of which the Mites live. Other allied species attack the buds of trees and materially injure their growth.

DEMODEX
FOLLICULORUM.

ORDER IV.—TARDIGRADA.

This is a small group of microscopic creatures commonly known as Bear- or Sloth-animalcules, found in moss and in wet places, and displaying some peculiarities which have for a long time rendered them exceedingly interesting to microscopists. They have a longer or shorter oblong-

ovate body, with faint indications of four segments, and upon each side four short conical limbs, the hindmost of which occupy the posterior extremity. The mouth is suctorial, and consists of a fleshy tube containing a pair of styliform organs, which can be protruded and retracted by the action of muscles; and the legs are terminated by three or four claws. No organs of circulation or respiration are recognisable in them.



MACROBIOTUS HUFELANDI.

They have another peculiarity distinguishing them from all the other Arachnida, namely, that they are absolutely hermaphrodite; the single ovary containing its eggs being always visible in the hinder part of the body, and at the posterior end of it are placed the male organs, both sets opening into a dilatation of the intestinal canal. In the course of the latter we see towards the head a strongly muscular pharynx, followed by a very large intestinal sac nearly filling the body, and surrounded by many small dilatations, giving it a clustered appearance. The walls of this part are glandular, and no doubt perform the functions of a liver; and in addition to these there are two large salivary glands which discharge their secretion into the mouth. Curiously enough, the nervous system acquires a considerable development, having four large ventral ganglia with double commissures. On the sides of the head there are a pair of eye-points.

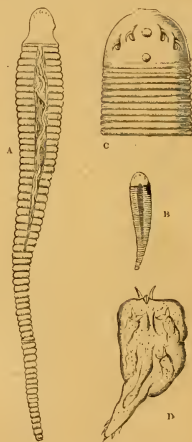
The systematic position of these curious little creatures was long a matter of dispute, although, so long since as 1785, the Danish naturalist, O. F. Müller, recognised their affinity to the Mites, and described a species under the name of *Acarus ursellus*. They live sometimes in water, but more

frequently in moss in damp places, and some of them are found especially in a rather curious locality, namely, the gutters of the roofs of houses. Like the Rotatorial animalcules which also occur in such places, the Tardigrada have the power of resisting desiccation. They may be found apparently quite dry among the sandy dust of a gutter, and will revive at once on being duly moistened. Their eggs, as may be seen from the figure, are of large comparative size and few in number, and they are generally deposited simultaneously with a change of skin of the parent animal, so that the cast skin serves as a protection to the young animals in hatching. The young resemble their parents, but are only about one-third the size. The known species are not very numerous. That figured is found in moss, and measures about one thirty-sixth of an inch in length.

ORDER V.—LINGUATULINA.

If the *Demodex folliculorum*, which we have referred to the Acaride, be worm-like in its appearance, the same may be said with still more force of the creatures belonging to the present order, when indeed for a long time were always classed among the Entozoa. The knowledge of their development, however, showed that they too were most nearly related to the Arachnida, and of late years they have taken their place among the aberrant forms of that class.

In the mature state, the Linguatulina are vermiform creatures, with a distinctly-ringed, and usually flattened, body, having at the anterior end a mouth furnished with a horny ring, and on each side of this two horny hooks, which can be protruded from small apertures. Their form and the presence of these hooks led to the creatures being regarded as allied to the Tape Worms. The male is usually much smaller and shorter than the female. The intestine passes straight from the mouth to the other end of the body, where the anal aperture is situated. Of the central



PENTASTOMA TENIOIDES.
A, female, natural size; B, male, natural size;
C, head of male, enlarged; D, young larva,
enlarged.

from the mouth to the other nervous system, the principal

part is a large ganglionic mass, forming a ring that embraces the œsophagus and gives off stems to various parts of the body; and no trace of respiratory organs can be detected, although, in some cases, there appear to be apertures in the skin representing stigmata.

From the researches of Van Beneden and Schubarth it appears clear that the Linguatulina undergo a retrograde metamorphosis, and that while in the young state they show a distinct alliance with the lowest Arachnids, in their adult form they present strong resemblances to the parasitic worms, and it is curious that, like the latter, they have to migrate from one animal to another in order to attain their sexual maturity. The best known species (*Pentastoma tenuioides*) is found when adult in the frontal and nasal cavities of the Dog and Wolf, where it doubtless causes much irritation. The eggs, when laid, are discharged with the mucus from the nose, fall upon plants, and are eaten with them by Hares and other mammals. The embryos hatched from these eggs, which show Arthropod characters, bore their way from the stomach into the liver, where they enclose themselves in a capsule, and change their skin several times. In about half a year they acquire the worm-like form, and again begin a migration, piercing through the liver, an operation which is sometimes fatal to their unfortunate host. Otherwise they again become encapsuled, and remain in this state until the animal containing them is devoured by some dog-like animal, when they at once make their way into the air-cavities, and wait there for their sexual maturity. This is the ascertained history of *Pentastoma tenuioides*, and it is believed that the other species of the group have the same habits. The number of known species is about twenty, but more have been recorded owing to the individuals encysted in the liver or lungs of herbivorous animals being taken for distinct species. They form the single family Acanthotheca.

ORDER VI.—PANTOPODA.

This order includes a small number of curious marine animals which have been regarded by different authors either as Arachnida or Crustacea, and really seem in some respects intermediate between the two classes. They have a cephalothorax of four distinct segments, which constitutes nearly the whole of the body, the abdomen being represented only by a small rudimentary part seen between the bases of the hind pair of legs. No respiratory organs can be recognised, but a three-chambered heart has been detected in them. The legs, of which there are four pairs (the first pair representing palpi), are long and many-jointed, and in general they bear such a proportion to the body that the name Pantopoda (All-legs) applied to the order is peculiarly appropriate. The order has also been called "Podosomata," which expresses very nearly the same idea. The mouth is suctorial and forms a sort of rostrum, projecting in front of the cephalothorax. At the base of this, on the back of the cephalothorax, four eyes are placed on a tubercle.



LARVA OF NYMPHON.



AMMOTHOA TYCNOGONOIDES.

a, rostrum; an, chelicerae; v, stomach; i, intestine; p, p, blind tubes.

In the interior the alimentary canal runs straight through the body, but the narrow stomach gives off on each side five blind tubes, which not only run towards the limbs as in the Arachnida generally, but actually traverse nearly the whole length of the legs, whilst the fifth (short) pair run up into the chelicerae. The sexual organs are situated in a very singular position in both sexes, namely, in the fourth or

fifth joint of the legs, so that there are eight of them. In the females, however, the eggs are extruded from an aperture in the second joint, and passed from this to a pair of accessory limbs springing from the first segment beneath the first pair of true legs; and to these they remain adherent until the young are hatched.

The larvæ when just hatched possess an unsegmented body and only two pairs of jointed legs; their chelicerae, which form nippers, often bear long lateral filaments, presenting a remarkable resemblance to the flagella of the antennæ in Crustacea, in fact, the little creatures may be well compared to the Nauplius form, as it is called, of many Crustaceans.

These very singular creatures are found in all seas, chiefly near the coasts, where they conceal themselves under stones, or cling to seaweed, and even to other animals. Occasionally they are met with adhering to fishes. In their movements they are slow and clumsy. A moderate number of species are known, generally of fair size, but in some deep sea dredgings large forms have been met with. They constitute two families, the Pycnogonidæ and Nymphonidæ.

The former (Pycnogonidæ) are generally of a more Crustacean aspect, and present a considerable external resemblance to certain Isopod Crustacea. They possess no chelicerae or palpi. *Pycnogonum littorale* is a common species upon all European coasts, where it crawls about under stones and among seaweed, with masses of which it is not unfrequently found floating upon the surface of the sea. This species is nearly half an inch long.

The Nymphonidæ have pincer-like chelicerae and palpi, and much longer legs than usually occur in the preceding family. The egg-bearing false-legs also are usually much longer than in the Pycnogonidæ, with which these animals agree generally in habits. The commonest European species (*Nymphon gracilis*) is about a quarter of an inch long. *Ammothoa pycnogonoides*, the species figured (p. 187), belongs to this family.

W. S. DALLAS.

CLASS CRUSTACEA.

CHAPTER I.

ANATOMY OF CRABS AND LOBSTERS.

Characteristics of the Crustacea—Their Mode of Existence—External Covering—Body Segments—Locomotory and other Appendages—Nervous System—Digestive Organs—Respiration and Circulation—Reproduction and Development—Metamorphosis—Exuviation—Repair—Classification.

THE Crustacea, represented by the Crab and Lobster, and a great variety of other crust-clad animals with jointed limbs, form the fourth class of the *Arthropoda*. Most of the members of this class seem to be essentially fitted to live in water, being furnished with branchiæ or gills.

Taking the Common Lobster for an example, the entire body and legs are encased in a hard structure which is called the shell, but it is quite different from that of a Whelk or of an Oyster. Neither is it composed of the same material as our own bones; nor is it horny, but it is formed of a nitrogenous substance, insoluble in alkalies, termed *chitin*, arranged in layers, between which salts of lime (mainly the carbonate) are deposited.*

This shell serves the double purpose of a defensive covering to the softer parts of the animal, and also, by means of its overlappings, infoldings, projections, and rugosities, of giving attachment and support to the muscles which move the limbs and also to those of the internal organs, as the stomach, &c. In the common Prawn and Shrimp this shelly envelope is quite thin and translucent, and its structure can be seen under the microscope without preparation; but in the Crab the shell is often very dense and thick, and needs to be cut into thin vertical sections, or rubbed down, before its structure can be clearly made out with the microscope. If a thin vertical slice be prepared, three distinct layers or strata will be seen, namely, first, a horny structureless layer covering the exterior; second, a cellular stratum; and third, a laminated tubular layer. The innermost and even the middle layers may, however, be altogether wanting, as in some larval forms (*e.g.*, *Phyllosoma*), or as in the delicate covering of the Shrimp, in which only the cellular and horny layers are present.

Dr. Carpenter remarks: "In the Common Edible Crab (*Cancer pagurus*) we can readily separate the structureless horny outer layer, after a short maceration in dilute acid, thus leaving the middle cellular layer exposed, in the cells of which the *pigment*, or colouring matter, of the shell is contained. The thick inner layer may be best seen by means of a section perpendicular to the surface of the shell, when we can, with a magnifying power of 250 diameters, observe the parallel laminae of which it is composed, and through which straight non-branching *tubuli* are seen to rise up at intervals through the cellular stratum forming little papillary elevations. It is from the thinness of the pigment matter in this layer, at these spots, that the coloured portion of the shell derives its minutely speckled appearance. In the shell of the Prawn we may notice the large star-shaped pigment or colour cells distributed over the surface, which, by concentration or diffusion of the colouring matter contained in them, tend to render them more like the sea-bottom which they frequent. In the Shrimps the cellular layer is not distinctly seen, whilst the calcareous portion forms concentric rings similar in structure to that seen in the papillæ of the surface of the deepest layer of the Crab's shell."

If any common Crustacean, such as a Lobster, Prawn, or Shrimp, be examined, it will readily be perceived that its body-covering is made up of a number of rings or segments jointed together, to which the feelers, claws, and legs are united by means of movable sockets. To give greater protection to the soft parts of their body, it often occurs, as in the Crab and Lobster, that a considerable number of these body-rings are soldered together into one piece, which may be compared to the back and breast-plate of a knight's armour. It was, however, discovered by naturalists long ago

* An analysis of the shell of the common Crab gives:—

Animal matter	28.6
Phosphate of lime	6.0
Carbonate of lime	62.8
Phosphate of Magnesia	1.0
Soda, salts, &c.	1.6

that all these Arthropod animals have one pair of jointed limbs to each ring or segment of their bodies; consequently, if there be one ring, whether of extra size or no, having more than one pair of limbs attached to it, one is justified in at once concluding that this particular joint or plate is composed of several separate rings soldered together. And this conclusion is really borne out by a study of the general structure of the class, and also by examining the larvæ, which, like those of insects, often show more clearly the true number of rings composing the body, because they are not soldered together so compactly as in the adult animal.

Take a Lobster, and try to comprehend its armour-plated body in detail. It appears to be made up of two chief divisions, namely, a large head-shield (*ca*), having a strong *rostrum* (*r*) or prow in front, like a ship's bowsprit, and behind this seven distinct and movable rings or segments, the seventh and last united to the sixth, and marked *t* in the engraving (Fig. 1). Each of these body-rings, save the hindmost, which is called the *telson*, has one pair of appendages attached to it, those of the last but one being expanded to form a broad and powerful swimming tail. The head-shield, however, covers no fewer than fourteen pairs of appendages, so that there ought to be as many as fourteen rings in this division, all more or less soldered together, thus making, with the body, no fewer than twenty-one segments.

In fact, this is the number of body-rings most generally found among the various members of this class, and although instances occur among the extinct group of the *Trilobites* and the living forms of the order *Branchiopoda* (see table, p. 196), in which a greater number than twenty-one segments can be detected, and also among the higher *Decapoda* (Crabs and Lobsters), in which fewer than twenty-one segments are visible, yet the former must be treated as "exceptions which prove the rule," whilst in the latter it can be shown that in their young or larval stages they do possess the full number of twenty-one segments, but that in the adult animal some of these become permanently soldered together. It is found convenient to treat the first seven of these rings as forming the head (*cephale*), and the second seven as the *thorax*, or middle body, and the last seven as the abdomen. But in the Crab and Lobster the seven body-rings forming the *thorax* are entirely concealed beneath the great overarching carapace or head-shield, which is really composed of the rings of the front segments of the head enormously developed, so as to cover over all the others in the Crab, and all but the last seven abdominal rings in the Lobster. If, however, this roof-like head-shield be carefully removed, the thin walls of the seven thoracic body-rings are actually to be seen there, only they are concealed beneath the overarching head-shield, each ring giving attachment to one out of the seven pairs of jointed legs belonging to this division of the animal's body.



Fig. 1.—DIAGRAM OF THE BODY SEGMENTS OF A LOBSTER.

ca, the Carapace, covering both the seven cephalic and the seven thoracic segments; *r*, the Rostrum; 1-6, rings of the Abdomen; *t*, the seventh and last ring, also called the "telson," or tail spine. The plates on each side of the tail are the modified appendages belonging to the sixth segment.

The first and most anterior pair of appendages in a Crustacean is composed of the two eye-stalks, each bearing an eye (Fig. 2, A) at its extremity. The *mouth*, which is placed in the centre of the head, just beneath the rostrum, has a small median plate in front, called the *labrum* (Fig. 2, B), or upper lip-plate, and a two-lobed piece behind it, called the *metastoma*, or lower lip (Fig. 2, C).

The second pair of appendages, following in order after the eyes, are called the antennules, or inner antennæ (Fig. 2, D), each consisting of a protopodite (or root-footlet) bearing two long, slender, many-jointed feelers, representing the two parts of an ordinary jointed limb, one being called the *exopodite* (or outer footlet), and the other the *endopodite* (or inner footlet). These undoubtedly serve as important organs of touch, and at the base of each in the protopodite is a small sac, opening externally by a narrow cleft guarded by hairs. At the bottom of this sac is a prominence wherein the auditory nerve terminates, and on which are very delicate hairs with silicious particles which have (apparently) found their way in from the exterior. The third pair of organs are the two great feelers or outer antennæ (Fig. 2, E), which exceed in length the entire body of the Lobster. Like the

maxillipedes have branchiæ attached to their bases. And now, in the succeeding five pairs of appendages, a marked change occurs, for these are undoubtedly legs, not jaw-feet. They vary at their extremities, the first three pairs being *chelate*, or clawed, at the end (Fig. 2, 1), whilst the two last pairs have simple extremities (u). The first pair (not drawn in our woodcut) are those enormously large clawed nippers, so characteristic of the common Lobster, and which differ in form (like a dentist's forceps), one being very heavy and blunt-toothed, and the other more slender, and having its pincer more sharply serrated. The remaining four pairs of legs are of nearly equal size, and are true walking limbs. The seven pairs of thoracic appendages carry the breathing organs (*branchiæ*) upon their basal joints, or attached to the *pleuræ* or side-walls of the thoracic somites (body-rings). There are twenty of these structures on each side of the cephalothorax. They are pyramidal bodies, each consisting of a central ascending stem with numerous delicate horizontal branches through which the blood circulates. They are closely packed against the outside wall of each thoracic body-ring, and are protected from all liability to external injury by the overarched sides of the great carapace or head-shield. To aerate the blood thoroughly it is necessary that the water bathing the branchiæ should be incessantly renewed. This is brought about partly by the very movements of the legs, to the first joint of which they are nearly all attached, and partly by those long slender organs we have already noticed, attached to the basal joints of the maxillipedes and also to the legs, called *epipodites*, or upper footlets. These ascend between the gills, and serve not only to keep them apart from each other, but they also impart a slight degree of movement to them. The main agent, however, is the *scaphognathite*, or boat-like jaw, on each side (Fig. 2, H, *sc*), which continually spoons out the water from the gill-chamber in front, and thereby causes a fresh current to enter from behind.



FIG. 3. — THE THIRD RING OF THE ABDOMEN OF THE LOBSTER.

t, the tergum (or back plate); s, the sternum (or jaw-venter); pl, pl, the pleuræ (or side-rings, called also the epimeral pieces); p, p, the propodites, or first foot-joints, each bearing an epipodite or outer, and an exopodite, or inner podite, or foot, or swimmeret.

The fourteen anterior segments which form the head and thorax in the Crab and Lobster being so constantly found blended together in one, are frequently termed the *cephalothorax*, a very convenient name for this compound structure. The seven body-rings which follow (called the *abdomen*) are seldom so much altered that one cannot at once see the separate joints or segments of which the body consists. In the Lobster, as seen by the woodcut

(Fig. 1), all the seven rings can be readily examined separately, but in the Crab the abdomen is often quite small, almost rudimentary, and in one family (called the *Leucosiadae*) the joints are soldered together into one piece, forming a small hollow enamelled lid to protect the eggs. In Fig. 3 is seen the third ring of the abdomen of the common Lobster, which may serve to represent the main characteristics of the second, third, fourth, and fifth body-segments. Each of these has two paired appendages attached to the underside or *sternum* (s) springing from one "root-footlet" (p), and giving rise to two swimmerets, fringed with hairs, representing the inner (eu) and outer footlet (ex).

In the sixth body-ring these swimmerets are greatly broadened out, and the outer footlet is divided into two by a transverse joint. These broad swimmerets, with the seventh or terminal somite (before spoken of as the "telson"), together form the expanded termination of the abdomen, which, by its forward projection through the water, drives the animal backwards. But the appendages belonging to the first abdominal ring in the Lobster have their swimmerets modified, in the males, into a pair of grooved processes, each like a small bent marrow spoon, and in the female into flexible soft processes.

The primary function of the abdomen in the Lobster, Prawn, and Shrimp, is undoubtedly that of

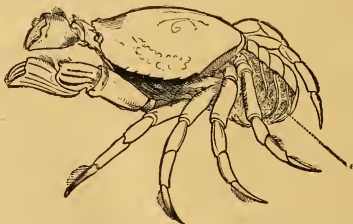


Fig. 4. — SIDE VIEW OF COMMON CRAB WITH ITS ABDOMEN EXTENDED. AND CARRYING A MASS OF EGGS BENEATH. e, THE EGGS. (After Morse.)

a powerful swimming organ, but in the Crab it is useless as an organ of natation, being quite rudimentary, especially in the males, but in the females of all these Crustaceans it serves as the nest for the eggs (or "berries," as the fishermen call them). When first extruded by the female, these eggs are coated with a viscid secretion, which thickens into threads, and causes the eggs to adhere to each other and to the fine hairs with which the swimmerets of the abdomen of the Lobster and of the female Crab are fringed, and, thus protected, they are carried about by the mother until hatched (Figs. 4, 5).

If a longitudinal section (Fig. 6) were made through the hard and soft parts of a Lobster, it would be found that its nervous system occupies the ventral, or belly surface, of the animal's body, and consists of two parallel chords, so closely united, that, save near the stomach, where they separate to form "the œsophageal ring," they present only the appearance of a simple chord having a single ganglionic enlargement at each segment of the thorax and abdomen. But where the gullet passes to the stomach, the most

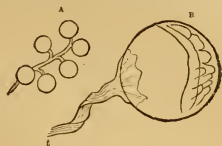


Fig. 5.—A, A FEW OF THE EGGS OF THE COMMON CRAB, ENLARGED. B, SINGLE EGG GREATLY ENLARGED, SHOWING MORE PLAINLY THE HARDENED THREAD (t) BY WHICH THEY ARE ATTACHED TO EACH OTHER. THIS EGG SHOWS THE YOUNG CRAB JUST BEGINNING TO FORM. (After Morse.)

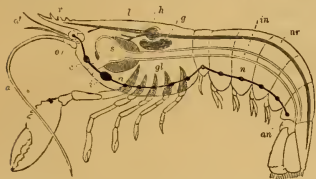


Fig. 6.—DIAGRAMMATIC SECTION OF A LOBSTER'S BODY.

a', the antennules; a, the antenna; r, the rostrum; h, the heart; ar, the artery (pl, the gills or branchiae); s, the stomach; l, the liver; g, genital organs or ovaries; in, the intestine; os, anus; p, n, the nervous system with its several ganglia or nerve masses; o, the optic ganglion; c, the cephalic ganglion; i, œsophageal ganglion.

anterior thoracic ganglion sends forward two distinct chords, which are united by a commissure or cross nerve behind the œsophagus, and have each a small ganglion on either side which gives off nerves to the mandibles, the stomach, the heart, the liver, and the intestines. These chords then unite once more in a single large ganglion in front of the mouth, and hence called the supra-œsophageal ganglion. This is the Lobster's brain, and its nerves go to the feelers, the eyes, and the other sensual organs of the animal. Above the nervous system is the alimentary canal, or the great duct or intestine by which the functions of digestion and nutrition are carried on.

We have already seen with what an array of

weapons, claws, foot-jaws, jaws, and mandibles, for cutting, crushing, tearing, biting, and generally pulling to pieces, a Lobster's mouth is armed; but, as if still further to insure perfect digestion, the stomach itself is provided with a set of calcareous teeth covered with strong ridges like the grinding surface of the tooth of a small Rodent or Kangaroo Rat. These gastric teeth (Fig. 7) triturate the food against a fixed calcareous ridge, also set in the wall of the stomach, and are moved by appropriate muscles. In the lower chamber of the stomach, leading to the intestine, and named the *pylorus*, a series of fine hairs are placed, which prevent the escape of the coarser particles of food, until they have been repeatedly subjected to the molar-like action of these gastric teeth. The liver in both the Crab and Lobster is a very large and highly complex organ, not solid like the human liver. The secreted fluid, or bile, is poured by two openings into the pylorus. Immediately beneath the cephalic shield of the Lobster lie the heart and the great main artery which supplies the entire length of the body. The heart consists of a single ventricle, which gives off six arteries by which the arterial blood is conveyed to the various organs of the body; it also receives by two main trunks the blood which has passed through the branchiae. The arteries have valves at their openings, and after ramifying they end ultimately in capillaries, connected at last with what are called

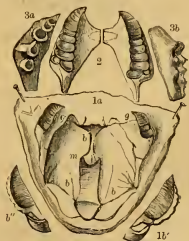


Fig. 7.—GASTRIC TEETH OF LOBSTER AND CRAB.

1a, stomach of Crab laid open; b, b, fixed calcareous place against which the two gastric teeth, g, g, are opposed; 1a and 1b, the two grinding teeth enlarged; 2, gastric teeth of Lobster; 3a, 3b, fixed gastric teeth of *Diliogriscia*, from Carboniferous limestone.

"venous sinuses." Here the blood is collected, and thence passes* up into the gills to be oxygenated, after which it is returned to the heart.

With the exception of the CIRRIPIEDIA (see p.196), the two sexes in the Crustacea are always distinct. Among many of the Crustacea, the antennæ and the great claws are specially developed in the male. This is the case in the claws of *Corystes* and *Macrophthalmus* and many others, whilst in *Cyclops* one of the antennæ in the male is specially modified for clasping the female. In the Crab the female lays eggs which have been already fecundated. In the Lobster the eggs are fecundated after their extrusion from the ovaries, whilst adhering to the abdomen of the female.

In nearly all the Crustacea the young undergo a series of metamorphoses after they quit the egg. This is especially the case with the truly marine forms. Among the DECAPODA (Crabs and Lobsters) some few species certainly quit the egg in the same form as their parents, with apparently the same number of jointed appendages to their bodies. This is the case with the River Cray-fish with several Land Crabs (*Gecarcinus*, &c.), with a species of *Dromia*, and with the common Garden Wood Louse (*Oniscus*, *Porcellio*, and *Armadillo*), which likewise nearly resemble their parents at birth.

One of the most interesting series of metamorphoses undergone by any of the Crustacea is that passed through by the young of the common Shore Crab (Fig. 8). In this species the

metamorphosis is a perfectly gradual one, and dissimilar as is the zoea when it quits the egg from the adult animal, yet nevertheless the change at each moult is so small that it is only by a comparison between the earliest and the last stages that the amount of the change which has actually taken place can

be fully appreciated. Thus, in the zoeid state the young Crab has fixed eyes without eye-stalks, a long body, destitute of any appendages; it has no walking legs, but it is a free-swimming form, performing its locomotion with its maxillipedes, or jaw-feet (*m*), which are greatly developed, serving as a pair of long oars, the long hairs of which probably fulfilling the office of branchiæ. Even when by successive moults the true ten-footed character is seen, the young nevertheless present at first a greater likeness to the long-tailed Lobsters than to the short-tailed Crabs. These transient characters displayed by the larvæ are

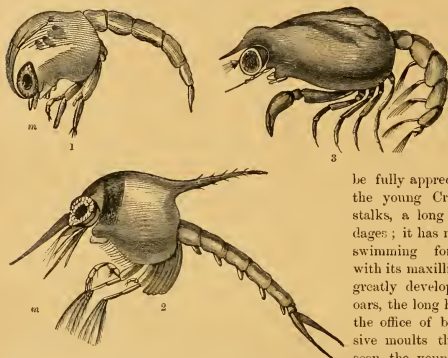


FIG. 8.—THREE STAGES IN THE METAMORPHOSIS OF THE COMMON SHORE CRAB. (*Carcinus maenas*.)

1, a newly hatched zoea; 2, a more advanced stage of same, 3, side view of still older larva (*Megalopa* stage). (After C. Spence Bate.)

found to be persistent in many of the lower and simpler forms now living, and they also characterised some of the ancient fossil Crustacea found in the Silurian formation. Thus it may be seen that the stages of development of the individuals of to-day are but a reflection of the life-history of the class in past geological time.

Still more strange are the changes undergone by the brood of some Prawns of the genus *Penæus* observed by Fritz Müller (Fig. 9-1, 2, 3, 4, 5). These quit the egg with an unsegmented ovate body (2), a single eye in front, and three pairs of swimming feet, of which the first pair are simple, and the other two pairs branched. In this stage, called the *nauplius*, there is no trace of a carapace, the paired eyes are wanting, and also the masticating organs, the mouth being covered by a helmet-like hood. After several moults the *nauplius* becomes a *zoea* (3), being furnished with maxillæ and two pairs of jaw-feet. The third stage of the same Prawn (4) exhibits still more remarkable changes, the paired eyes, the segments of the thorax, the rudiments of the feet are seen, all the appendages of the mouth and head can be counted, and the plates of the tail sprout forth. And now another great change takes

place, and the zoea passes into the *mysis* form (5); the antennae cease to serve as organs of locomotion, their place being taken by the thoracic feet, which are furnished with long hairs or bristles. The



Fig. 9.—METAMORPHOSIS OF A PRAWN OF THE GENUS *Penaeus*. (After Frits Muller.)

1, adult, half natural size; 2, nauplius stage of young Prawn as it quits the egg; 3, zoea of some Prawn; 4, older zoea of same species; 5, *mysis* form of ditto. (2, 3, 4, and 5, are all magnified forty-five diameters.)

abdomen is fully developed but has no appendages. Nothing can well be imagined more diverse than the *zoea*, *nauplius*, and adult stages in the life history of this Prawn.

Although the young of nearly all the Crustacea pass through numerous moults before attaining the adult state, yet, even after maturity, the shelly envelope is not permanently retained, but is exuviated and renewed as often as the growth of the animal necessitates its enlargement. By this wonderful provision the otherwise inelastic corselet is prevented from interfering with the continued growth of its wearer. The process of moulting is exactly analogous to the shedding of the skin and scales in reptiles. In *insects*—as all know who have kept silkworms—this moulting takes place several times in the *grub* or *larva* before it finally arrives at the perfect state. It then occurs no more. Insects, therefore, cannot grow after they reach the imago, and their life is consequently soon ended. Crabs, on the contrary, go on moulting and growing larger for many seasons, and each year they lay their eggs, so that they are more prolific, although less highly organised, than the insect tribe. The manner in which Crabs cast off their old shell is very singular, usually without producing any change in their external form, and when they have quitted the old habitation the whole body is already covered with a new suit of armour, which is, however, still soft, and does not acquire its requisite solidity for some hours, or even days after the operation.

The Crustacea also possess the power of reproducing injured or lost limbs; if one or more distant joints of a limb be torn off, the animal has the power of throwing off the remainder of the limb. This separation always takes place at the base of the first joint. The perfect restoration of the limb is not effected at once. After the first moult a new limb is produced of diminutive size. After a second, the new limb is very nearly twice as large as at the first, and at the third it advances nearly to its natural bulk and form. It is said that the noise of a thunderstorm or the discharge of a cannon will cause Crabs and Lobsters to throw off their claws; the same effect is also produced by the infliction of any sudden injury. The Broad-clawed Porcelain Crab (*Porcellana platycheles*), if seized by the claw, will leave it behind him and beat a retreat without it.

The accompanying table may serve to convey a general notion of the Crustacea as a class.

CLASS CRUSTACEA.

DIVISIONS.	LEGIONS.	ORDERS.
I.—THORACIPODA.— <i>Special locomotory organs belonging to the thorax.</i>	1. PODOPTHALMIA.—Eyes on movable foot-stalks. Branchiæ proper almost always present. Thorax covered more or less completely by cephalic shield.	DECAPODA. Five pairs of thoracic feet. <ul style="list-style-type: none"> a, BRACHYURA. (Short-tailed.)—Crabs. b, ANOMOURA. (Varicous-tailed.)—Hermit Crabs. c, MACROURA. (Large-tailed.)—Lobsters, Shrimps.
	2. EDRIOPHTHALMIA.—Eyes fixed. Branchiæ formed of modified appendages. Limbs usually seven pairs. No cephalothoracic carapace.	2. STOMAPODA. (Mouth-footed.)— <i>Squilla</i> , <i>Mysis</i> , &c.
	3. MEROSTOMATA.—The mouth furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet.	3. ISOPODA. (Equal-footed.)—Wood Lice, <i>Oniscus</i> , <i>Idotea</i> , &c. 4. AMPHIPODA. (Both feet.)—Sand-hoppers, <i>Talitrus</i> , <i>Gammarus</i> .
II.—GNATHOPODA.— <i>Limbs nearly always belonging to the head, but not generally specialised, as their bases perform the part of jaws. Branchiæ usually exposed and aiding in natation.</i>	4. BRANCHIOPODA.—Most of the appendages, save those of the head and mouth, converted into lamelliform branchiæ.	5. XIPHOSEURA. (Sword-tails.)—King Crabs, <i>Limulus</i> .
	5. LOPHYPOPODA.—Locomotory organs having stiff hairs. Branchiæ attached to mouth organs.	6. (EURYPTERIDA. <i>Extinct</i> .)— <i>Eurypterus</i> , <i>Pterygotus</i> , &c. 7. (TRILOBITA. <i>Extinct</i> .)—Trilobites, <i>Calymene</i> , <i>Phacops</i> , &c. 8. PHYLLOPODA. (Leaf-footed.)— <i>Apus</i> , <i>Branchipus</i> , &c. 9. CLADOCERA. (Branched horns.)—Water Fleas, <i>Daphnia</i> , &c. 10. OSTRACODA. (Shell-covered.)— <i>Cypris</i> , <i>Cardovia</i> , &c. 11. COPEPODA. (Oar-footed.)— <i>Cyclops</i> , <i>Diaptomus</i> , <i>Cyclopus</i> , &c.
III.—ANCHORACEPHALA.— <i>Adult (female) attached by the head, and permanently fixed.</i>	6. CIRRIPEdia.—Adult animals permanently attached to some living or dead object. Sexes usually united.	12. RHIZOCEPHALA. (Root-headed.) Parasitic forms.— <i>Peltostomus</i> , <i>Saccalina</i> , &c. 13. BALANIDE. (Acorn shells.)— <i>Balanus</i> , <i>Coronula</i> , &c. 14. LEPANIDE. (Barnacles.)— <i>Lepas</i> , <i>SculpeLLum</i> , <i>Pollicipes</i> , &c.

CHAPTER II.

CRUSTACEA (*continued*).—CRABS, LOBSTERS, AND SHRIMPS.

BRACHYURA, CRABS—Cephalisation—Sizes of various Crabs—The Spider Crabs—The Great Crab—The Common Shore and Harbour Crab—The Swimming Crabs—The Velvet Fiddler Crab—The Masked Crab—Land Crabs—The Pea Crab—ANOMOCRA, HERMIT CRABS—Their Houses—The Land Hermits—The Robber Crab—MACROURA, LOBSTERS—The Common Spiny Lobster—The Common Lobster—The Norway Lobster—The Common River Crayfish—The Eye of Crustaceans—The Brown Shrimp—The Common Prawn—Blind Crayfish.

FIRST LEGION.—PODOPHTHALMIA.

ORDER DECAPODA.—BRACHYURA (CRABS).

THE Crab is certainly the highest representative of the Crustacean class, and in this ten-footed order are included some of the most active and intelligent members of the community, the Land Crabs and Shore Crabs, and also the largest representative of the class, the *Inachus kempferi*, from Japan. Crabs furnish the best illustration among the Crustacea of that concentration of organs around a single nerve-centre, which has been aptly termed *cephalisation* (Fig. 10). Instead of a long body composed of a large number of rings, each having its own nerve-ganglion (Fig. 11), we have in the Crab one large cephalothoracic ganglion (*r*) representing nearly the entire nerve force of the body, the supracervical ganglion (*c*) only giving rise to the nerves of sense and volition.

The highest concentrated type of Crustacean is exemplified by *Maia* and the Spider Crabs, but, as a matter of fact, the Triangular Crabs, of which *Maia* and *Inachus* are examples, do not embrace, by any means, the liveliest and most intelligent of the order. The carapace in these is narrow in front,



Fig. 10.—NERVES OF *MAIA* *SQUINADO*.



Fig. 11.—NERVES OF AMPHIPOD (*Talitrus*, *a*), ISOPOD (*Cymothoa*, *b*), AND LOBSTER (*Homarus*, *c*).

and generally forms a prominent beak, beneath which the mouth is situated. Notwithstanding the length of their legs, their movements are generally sluggish. Many of these Crabs are quite coated over with nullipore and corallines, while others cultivate green and red seaweeds upon their backs, and thus disguised like Indians stalking game, they can readily approach their more active prey, then by a sudden and unexpected snap they will seize upon and hold with extraordinary firmness the small fishes which incautiously venture too near their ambush.

Although the British and European examples of *Stenorhynchus*, *Acheus*, *Pisa*, *Inachus*, *Arctopsis*, and *Hyas*, are all quite small forms of Crustacea, and even *Maia* is by no means a large Crab, yet in the British Museum there are specimens of the *Inachus kempferi* from Japan which measure ten feet between the tips of the clawed fore limbs; the body (like that of other of the Triangular Crabs) is comparatively small and rather convex in shape: the claws are thin and about six feet in length. These monstrous Crabs are said to be eaten in Japan.

The Slender-beaked Spider Crab (*Stenorhynchus tenuirostris*) is one of the most curious of these triangular Crabs. When alive it is of a lovely pink and puce colour, the ova are of a light orange-brown. When seen sitting in a group of corallines of darker hue it presents a striking object in an aquarium. This species is frequently to be met with at Torquay in deep water. It is remarkable for the great length of its rostrum, which equals that of the entire carapace. Its small body and exceedingly long and slender limbs make this form the most spider-like of all the Spider Crabs (see Fig. 12).

The Four-horned Spider Crab (*Pisa tetraodon*) is a good illustration of one of the commonest of these small British Crustaceans. Like all the group, the carapace is triangular and elongated in front; the rostrum is large, strong, and prominent, and forms two strong horns. The margin of the carapace is also armed with spines, and the surface has numerous tubercles and hairs upon it. The abdomen of the female is very large and broad, and when laden with eggs exceedingly prominent. They are abundant at Bognor and other points along the south coast of England, and being attracted, like their larger brethren, by the smell of

stale fish, they frequently enter the Crab and Lobster-pots to the number of twenty to thirty, and so meet with an untimely end. They are usually so overgrown with corallines as to be almost indistinguishable.

The Spinous Spider Crab (*Maia squinado*) has a very convex and circular carapace, growing more triangular with age by the increased length of the rostral portion (Fig. 13). The centre of the carapace has a group of seven rounded and swollen prominences, and the whole surface is covered with minute spines and tubercles, with larger spines on the sides and front border. The rostrum has two strong and prominent diverging horns. The antennæ are small. The chelate fore legs are considerably longer and stouter in the adult male and much smaller in the young and in the adult females. There are few Crustacea in which age produces so great a change of form as in the Spider

Crab. In the young state the fore legs are slenderer and shorter, and the front of the carapace is broader in proportion. *Maia* is common to the western and southern coasts of England, and is also found on the southern coast of Ireland. It is by far the largest species of the family, and, with the exception of the Great Crab (*Cancer pagurus*), it is the largest of the British Brachyura. The carapace of a specimen taken in Plymouth Sound measured eight inches in length and nearly six in breadth, whilst the length of the fore limbs was fifteen inches. It is eaten by the poorer classes, though it is but indifferent food. Like all the other triangular Crabs, the fishermen inveterately term it



Fig. 12.—SLENDER-BEAKED SPIDER CRAB. (*Stenorhynchus tenirostris*. Leach.)

“spider,” and they appear to have very little idea of any affinity between these forms and the Crabs, properly so called. Some years since Professor Bell saw in one of the back streets of Poole, near the waterside, a little girl standing by a small table, on which was a plate containing two of these Crabs of moderate size, cooked and for sale. On being asked by the Professor, “Pray, do they eat these Crabs here?” she replied, with a look of great surprise at his ignorance, “They ben’t Crabs, sir, them’s spiders!”

The Great Crab (*Cancer pagurus*) is one of the most familiar forms of all the Crustacea, because one meets with it on the stall of every fishmonger, and in England it is largely consumed as an article of food, especially in all the great cities. Its chief feature is that the external antennæ have a very long and thick basal joint; the terminal portion, or feeler, is very short and slender. The great claws have black tips, and are equal in size, and of great strength and thickness. The carapace is nearly plain, with an oblong ovate outline much broader than long, the anterior border being marked by a row of ten square uniform teeth. The great claws and carapace are smooth, and the four simple walking legs are hairy.

This Crab was eaten in the time of the Romans, and has formed an article of diet probably ever since that period. Its excellence is mainly due to the enormous development of the liver, which occupies the two anterior sides of the carapace, and is deemed by most the “tit-bit.” Its picture may be seen in one of the beautiful tessellated Roman pavements in the British Museum.

The fishery for these Crabs constitutes an important trade on many parts of the coast. The

number annually taken is immense, and as the occupation of procuring them is principally carried on by persons who are past the more laborious and dangerous pursuits of general fishing, it affords a means of subsistence to many a poor man who, from age or infirmity, would be unable without it to keep himself and his family from the workhouse. They are taken in what are termed "crab-pots," a sort of wicker trap, made by preference of the twigs of the golden willow (*Salix vitellina*), at least, in many parts of the coast, on account, as the fisher-folk say, of its great durability and toughness. These pots are formed on the principle of a common wire mouse-trap, but with the entrance at the top. They are baited with pieces of fish, generally of some otherwise useless kind; these are fixed into the pots by means of a skewer. The pots are sunk by stones attached to the bottom; and the situation where they are dropped is indicated, and the means of raising them provided, by a long line fixed to the creel, or pot, having a piece of cork attached to its free end. These pieces float the line, and at the same time serve to designate the owners of the different pots, one perhaps having three corks near together, towards the extremity of the line, and two distant ones; another may have one cork fastened crosswise; another two fastened together, and so on.

The Common Shore Crab (Fig. 14, *Carcinus maenas*), so abundant in very shallow water around the coasts, and so industrious a scavenger between tide-marks, spends really much of its time almost out of water or on the edge of the advancing and the skirts of the receding tide. It is a true running Crab, yet its relations are all swimming Crabs, having their hind pair of feet specially modified for swimming, which is not the case in *Carcinus*. The front margin of the carapace is strongly toothed with five teeth on each side, and three lobes in front; the eyes are larger and certainly more useful "optics" than those of the great Crab. To any one who is a lover



Fig. 13.—*MAIA SQUINADO*.

of an aquarium this very common Crab is an excellent and amusing species to keep and tame, for it soon loses all idea of shyness, and will "come to be fed" like any other pet, and take its food sharply. When very young these Shore Crabs moult frequently, and, being easily kept in small vessels of sea-water, one can all the more readily study their habits. One which was thus kept in confinement moulted on 11th April, 22nd May, the 3rd July, the 30th August, and 26th September of the same year, the acceleration of the last moult being attributed to the creature having been fed "like a prize beast," on purpose to try the effect on its growth. In casting its shell a Crab not only parts with every joint and plate of its many-jointed body, antennae, foot-jaws, claws, and tail, but the very lining of its gills, of its stomach, of its eyes, and of other parts, is thrown off, and thus, when the creature has escaped, the shell seems as perfect nearly as the animal itself.

Pennant's Swimming Crab (*Portunus variegatus*) has a carapace which is rather longer than wide, and is toothed at its front border. Its fore legs are short, with exceedingly sharp claws (chela). The last pair of legs are flat and spatulate, and like an oar-blade, well adapted for swimming; the other three pairs of simple legs are fitted for running. They are common on the shores of the Firth of Forth and the Moray Firth, and in Ireland. Its colour is a dull purple-white mottled with a darker hue.

The Velvet Fiddler Crab (*Portunus puber*) has its front border armed with at least ten spines, and its entire carapace densely covered with hairs. The chela, or claws, and also the four pairs of simple legs, are thickly coated with a dense pile of fur. All the limbs have raised longitudinal lines or ridges upon their joints. The general colour of the Velvet Fiddler Crab is brown, but the longitudinal ridges on the legs are blue. This Crab is not uncommon on the south-west coast of England

and on the Irish coast. It is also met with in the Moray Firth, the Firth of Clyde, and in the Channel Islands, where it is known as the Lady Crab, from its velvet coat.

"An old male of the Velvet Fiddler is a striking and handsome Crab. His body generally is clothed with a short velvety pile of a pale brown or drab hue, from beneath which here and there shines out the glossy deep black shell, especially where rubbed, as at the edges. The feet, particularly the plates of the oars, are conspicuously striped with black, the large and formidable claws are marked with bright scarlet and azure, as are also the foot-jaws and face, while the eyes are of the richest vermillion, projecting from hollow black sockets." This species, when apprehensive of assault, uses its powerful claws "to strike transversely, as a mower uses his scythe."

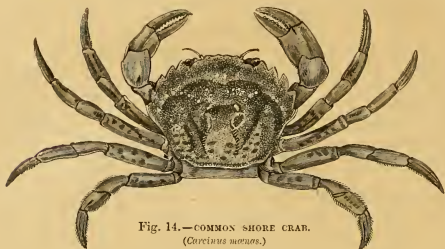


Fig. 14.—COMMON SHORE CRAB.
(*Carcinus maenas*.)

the carapace even in the female is remarkably flat, and its form is nearly orbicular. The edge of the carapace has five teeth on each side. The eyes are keen and active; the chelæ are exceedingly sharp-edged. The four following pairs of limbs are all adapted for swimming. The colour is of a rich reddish-brown. The texture of the whole shell is far lighter in density than any of the coast species which live inshore. This is, in fact, a truly pelagic or open-sea Crustacean. The writer has seen this Crab in large numbers swimming on the surface of the Bay of Biscay one hundred miles from land; and far off the coast of Cornwall the fishermen take them in the act of eating the Mackerel, which they pursue and fasten on to with their knife-like nippers, until the terrified fish becomes exhausted and is speedily vanquished and devoured.

A much larger species of Swimming Crab than the British, named *Portunus pelagicus*, occurs in the seas of China and Japan, and extends as far south as the Gulf of Carpentaria. It preys upon quite large fishes, and is "built," as shippers would say, "for speed and lightness." Its habits were well known to the Japanese, who have depicted this Crab most accurately in one of their many wonderful picture-books, printed from wood blocks, preserved in the British Museum. The *Portunus* is represented in the very act of catching a live fish many times larger than itself. These predaceous Swimming Crabs are much disliked by the fishermen, because, when they are taken in the nets with a haul of fish, they bite and mutilate all within their reach, as does the Dog-fish and the other small Sharks common along the coast.

Corystes cassivelaninus (Fig. 16). In this singular Crab the carapace is longer than it is broad. The surface of the carapace is convex, and the regions somewhat distinctly marked by a groove surrounding the heart, the intestinal and genital regions, forming altogether a remarkable resemblance to the features of the human face, from which circumstance it has obtained the name of "the Masked Crab." The sexes of this Crab differ so much in appearance that they have been described as separate species. It is frequently to be obtained on the south and west coast of England and Wales. The habit of this Crab is to lie buried in sand with only the antennæ visible above the surface. This is a very ancient type of Crustacean; many representatives of it (*Palæocorystes*) occur fossil in the Cretaceous beds (Gault and Greensand) of England.



Fig. 15.—HENSLOW'S SWIMMING CRAB.
(*Polybius henslowii*.)

As we have already pointed out, the branchiæ or gills are enclosed between the side walls of the thorax and the over-spreading head-shield (the "Crab-cart" of peasants' children in the English Eastern Counties), and are borne upon the basal joints of the thoracic limbs. As rapidity of movement necessitates increased activity in the circulation of the vital fluid in the body, we thus find that by this simple arrangement the branchiæ are brought directly into connection with the appendages specially engaged in locomotion. In a precisely similar manner we observe that the pectoral muscles in the bird, by their rapid action, accelerate their respiratory functions, consequently those birds whose flight is swiftest, such as the Swallows, naturally breathe most quickly. Amongst the Land and Shore Crabs, such as the *Grapsida*, the *Ocypodida*, the *Gecarcinida*, we find some of the most rapidly moving terrestrial forms of Crustacea. Respiration in these Crabs is, however, carried on essentially upon the same plan as in the aquatic species, that is, by means of *moistened branchiæ* or gills, not by pulmonary sacs, as in the Arachnida, nor by tracheæ, as in insects proper. Nevertheless, the aëration of the blood in the branchiæ of Land Crabs is so much more complete than it is among the aquatic species, that the Land Crabs are easily drowned by continued immersion in water.

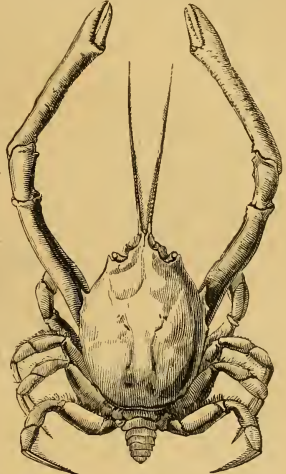


Fig. 16.—MASKED CRAB. MALE.
(*Coryptes cassipolaeus*)

Land Crabs are met with in the tropics in vast numbers. Of these, the most common and best known to us is the *Gecarcinus ruricola*, or "Countryman Crab," once so abundant in the highlands of Jamaica, and still so formidable in Montserrat and other West Indian sugar-producing Islands (Fig. 17). When the season for spawning arrives vast armies of them set out from the hills, and, undaunted by opposition, march in a direct line towards the sea-shore for the purpose of depositing their eggs. Having reached the destined limit of their journey, they deposit their eggs below high-water mark in the sand, and re-commence their toilsome march towards their upland retreats. On their seaward journey they are in full vigour and fine condition, and this is the time when they are caught in great numbers for the table. Their flesh, which is of the purest whiteness, is highly esteemed, but, like that of all Crustaceous animals, is rather difficult of digestion. On returning from the coast they are exhausted, poor, and no longer fit for use. They then retire to their burrows, where they exuviate, or shed their shells, a short time after which operation, and while in their soft state, they are considered by black connoisseurs to be a great delicacy. These Crabs, which take up their abode in the vicinity of sugar-cane fields, are very injurious to the planter, some of the species being particularly fond of the cane, the juice of which they suck and chiefly subsist upon. They also attack and destroy the growing shoots of the young plants.

Cardisoma carnifex, which usually inhabits the mangrove swamps of the West Indian Islands, lives principally upon the fruit of a species of *Annona*, which grows in those places. But nothing comes amiss to it. Those individuals whose residence is in the neighbourhood of the cemeteries are said to burrow down to get at the dead bodies, and Dr. Duchassaing tells us that the West Indian burial grounds are pierced in every direction by burrows of these animals. Nevertheless, the *Cardisoma* is regarded as a luxurious article of food by West Indians, who, however, take care not to eat those which are obtained in the mangrove swamps, as far as possible from the cemeteries. They are caught in box-traps baited with a piece of their favourite fruit, and after their capture they are usually kept some time, and fattened with broken victuals.

Land Crabs are very abundant in the Deccan; they have been found on the table-lands at an elevation of nearly 4,000 feet. But as they do not perform an annual migration to the sea for the purpose of depositing their eggs, it seems highly probable that the Deccan species frequents the margins of streams, and deposits its eggs in fresh water, in which case the nearest river would serve the same purpose; for the young must undergo their metamorphosis either in the water or within the

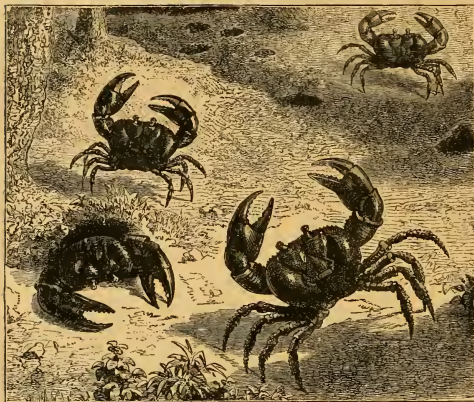


Fig. 17.—VIOLET LAND CRAB OF JAMAICA. (*Gecarcinus ruricola*.)

Horseman Crab, from Rio, is another interesting species of Land Crab. It makes a loud grating sound by means of a series of small ridges on the inner surface of the hand against the prominent edge of the second joint of the same pair of legs. There is really no voice organ (truly so called) in any of the Invertebrata. Mosquitoes "sing," Bees "hum," Crickets "chirp," and Beetles "drone;" but these are all mechanical noises, made by movements of wings or legs, not with such a contrivance as the human throat. Most of these sounds are produced by an arrangement similar to that of the fiddle-bow drawn across the strings of the fiddle, whilst many of the harsher sounds have been aptly compared to the noise produced by street-boys scraping a stick along a row of iron railings.

The Pea Crab (*Pinnotheres*) is an interesting genus, both on account of its diminutive size and from its singular practice of making its habitation within the valves of living bivalve shells. The writer has taken numbers of them alive from shells as small as *Astarte* and *Cytherea* at Malaga. One species (*Pinnotheres pisum*, Fig. 18) is so common on the Irish coast, that Mr. W. Thompson obtained fourteen of them, by opening eighteen of the larger or Horse Mussel, dredged off the shore of County Down; and in the common Cockle at Youghal Mr. Ball found them so abundantly, that about nine out of every ten Cockles contained a Crab. Two and even three Crabs are occasionally found in one Mussel, or in one *Pinna*.

Pinnotheres veterum is the species found in the Mediterranean, whose history, mingled with much fable, is recorded by some ancient authors.

The ANOMOURA, or irregular-tailed Crabs, form the connecting link between the Crabs and Lobsters, for, besides the Hermit Crabs proper, which are generally considered typical of the

egg itself before it is hatched, several authentic instances of which are known. Another form, the Calling Crab (*Gelasinus*), is a great burrower, inhabiting the coasts of Brazil, &c. He has one large hand and a small one, and from the way in which he is compelled to run in order not to overbalance himself with his big claw raised above his head, as if beckoning, he has obtained the name of Calling Crab. This powerful hand is used in throwing the earth and sand out of its burrow when digging, which he does most vigorously to a distance of a foot or more from the hole.

The *Ocypoda*, or



Fig. 18.—PINNOTHERES PISUM.



GROUP OF HERMIT CRABS.

- 1, Hermit Crab in *Achatina* shell ; 2, Hermit Crab in Turbo shell ; 3, Hermit Crab with Sea Anemone attached to its shell ;
 4, Hermit Crab in the act of shifting from one Whelk-shell to another.

Anomourous type, there are many forms which, save for the abortive character of the posterior pair of thoracic limbs, and their modified jaw-feet, might be placed with true Crabs or true Lobsters—*Dromia* with the former, and *Galathea* and *Munidia* with the latter. Others again, like *Lithodes*, have the plates of the abdomen irregular or partly membranous, whilst in the true *Paguri* they are entirely unprotected by hard shelly plates. In the East and West Indies, and in the tropics generally, there are many species of *Anomoura* which live wholly or partially away from the sea, adopting terrestrial habits of life, and even becoming great climbers. They are met with living in forests often miles from the sea, and if land shells are not to be found, one species of Hermit Crab (*Cenobita brunnea*) protects its soft tail with an empty nut-shell, in which it makes itself perfectly at home.

The *Cenobita diogenes* (Fig. 20) is found on bushes a few hundred yards only from the sea living in empty land shells. It is abundant in all the West Indian Islands, and has been more than once brought over to England alive with cargoes of guano. The writer kept one for some weeks in a fern-case in his study. It was housed in an *Achatina* shell, and no doubt it might have continued to live to this day, but it could not be induced to eat, and it was exceedingly difficult to discover what its proper food should be. This little Crab was a splendid climber, and its feats of agility were often surprising. It burrowed under stones, and seemed fearful of being looked at.

Charles Darwin says, "In every part of Keeling Island one meets with Hermit Crabs of more than one species, carrying on their backs the houses they have stolen from the neighbouring beach. The large claws or pincers of some of these Crabs are most beautifully adapted, when drawn back, to form an *operculum* to the shell, which is nearly as perfect as the proper one that belonged to the original molluscous animal. Certain kinds of these Hermits always select certain old shells only to live in."

The most remarkable of the Land Hermits is the *Birgus latro*, or Robber Crab (Fig. 19). Darwin says, "Keeling Island has no quadruped excepting the pig, and no vegetable in quantity excepting the cocoa-nut. On it the pigs, which are loaded with fat, almost entirely subsist, as likewise do the poultry and ducks. Even a huge Land Crab is furnished by nature with a curious instinct and form of legs to open and feed upon this same fruit. It is very common on all parts of the dry land, and grows to a monstrous size. It is closely allied or identical with *Birgus latro*. This Crab has its front pair of legs terminated by very strong and heavy pincers, and the last pair by others which are narrow and weak. It would at first be thought quite impossible for a Crab to open a strong cocoa-nut covered with the husk, but Mr. Leisk, one of the two British residents, assures me he has repeatedly seen the operation effected. The Crab begins by tearing the husk, fibre by fibre, and always from that end under which the three eye-holes are situated. When this is completed, the Crab commences hammering with its heavy claws on one of these eye-holes till an opening is made; then, turning round its body, by the aid of its posterior pair of narrow pincers it extracts the white albuminous substance. I think this is as curious a case of instinct as ever I heard of, and likewise of adaptation in structure between two objects apparently so remote from each other in the scheme of nature as a Crab and a cocoa-nut tree."



Fig. 19.—*BIRGUS LATRO*.

"The *Birgus* is diurnal in its habits, but every night it is said to pay a visit to the sea, no doubt for the purpose of moistening its branchiæ. The young are likewise hatched, and live for some time on the sea coast. These Crabs inhabit deep burrows, which they excavate beneath the roots of the cocoa-nut trees, and here they accumulate surprising quantities of the picked fibres of the cocoa-nut husk, on which they rest as on a bed. The Malays sometimes take advantage of their labour by collecting the coarse fibrous substance and using it as junk. These Crabs are very good to eat;

moreover, under the tail of the larger ones there is a great mass of fat, which, when melted, sometimes yields as much as a quart of limpid oil. It has been stated by some that *Birgus latro* crawls up the cocoa-nut trees for the purpose of stealing the fruit. I very much doubt the possibility



Fig. 20.—HERMIT CRAB (*Cenobita*) IN SHELL.
(After Morse.)

of this, but with the *Pandanus** the task would be very much easier. I understood from Mr. Leisk that on these islands the *Birgus latro* lives only on the nuts which fall to the ground." (C. Darwin: "A Naturalist's Voyage Round the World.")

The friendship—interested or otherwise—cemented between Soldier Crabs and Sea Anemones is very remarkable. One Sea Anemone, the *Sagartia parasitica*, seems to be on very friendly terms with the Hermit Crabs, always selecting for its place of attachment the dead shell of some whelk tenanted by one. The Crab who sustains the honourable office of porter to this Anemone is invariably the *Pagurus bernhardus*.

Prof. Dana mentions another *Actinia* from the China Seas—the *Cancerisocia expansa*—which associates with *Dorippe* (an anomourous Crab), who holds the *Actinia* on its back with its two posterior pairs of legs.

DECAPODA—MACROURA. (LOBSTERS.)

The Macrourous (or large-tailed) type of the order (DECAPODA) is represented by the Lobster, essentially an aquatic form, and possessed of great powers of locomotion. The hinder segments of the body (termed the abdomen) are very much developed, and of nearly equal growth, being also compressed at the sides, so as to be somewhat cylindrical in form. They present a well-marked difference from the tail of the Crab (BRACHYURA), in which the segments are short and flattened, and expanded laterally. The abdomen in the Lobster is also terminated by a broad swimming tail.

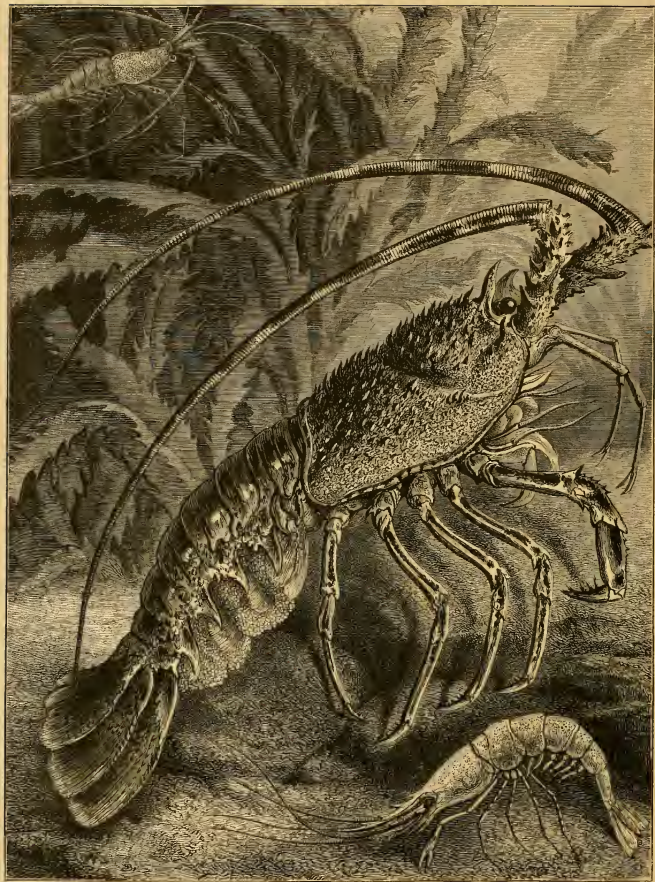
The members of this division are very abundant numerically in both marine and fresh water.†

The Common Spiny Lobster (*Palinurus vulgaris*) has thick, extremely long, and stiff external antennæ, the basal joints of which are very large, and unite to form the front of the mouth. The three following joints are large, thick, and spinose. Each antennule has three very long and slender cylindrical basal joints with two small feelers at its tip. The outer jaw-feet are formed like feet. The true walking legs are all one-toed at their extremity. The first pair, however, which are thicker and shorter than the others, has a spine on the border of the last joint but one against which the last joint shuts, thus forming a rudimentary chela or nipper. The carapace is extremely rugose, being covered with spines and tubercles. The body segments are large, and the tail-fins well developed for swimming. The family of the *Palinuridae* are of very ancient origin, going back in geological time to the Solenhofen rocks (Oolitic age). Only one genus now survives.

The genus *Palinurus* comprises several large edible species, one of which, the Common Spiny Lobster (*P. vulgaris*), inhabits the English western coasts, and is brought thence in large quantities to London. They are found chiefly on rocky coasts, and are often taken in the crab-pots. Great numbers of this Lobster are also eaten in France. Its flesh is much esteemed, though by some considered inferior in flavour to that of the Common Lobster (*Homarus vulgaris*). It reaches about a foot in length, and sometimes as much as eighteen inches. The antennæ are very long, just twice the length of the entire body. The carapace is thickly covered with spines of various sizes, and all the species have a large spine over each eye.

* *Proceedings of the Zoological Society*, 1832, p. 17.

† In his book on the Crayfish, Prof. Huxley mentions, that, in Tasmania, the genus *Engseus* (one of the *Parastacidae*), a small kind of Crayfish, lives habitually on land in burrows, which they excavate in the soil (p. 306) and *Parastacus pilimanus*, from Santa Cruz, in the upper basin of the Rio Pardo, an affluent of the Jacuhy, was obtained "by digging it out of holes in the ground" (p. 308). So that the Crayfish is an exception to the general rule, that all the Macroura are truly aquatic in their habits, and that none are terrestrial.



SPINY LOESTER (*Palinurus vulgaris*).

[Female, bearing eggs attached to the false abdominal swimming-feet.]

The *Palinuri* live on mollusca and on other marine animals. They have the power of producing a very loud noise, by rubbing the first joint of their exterior antennæ against the projecting border of the carapace, or head-shield. Aristotle, Athenæus, and Pliny were acquainted with the animals of this genus, which they named *Locusta*; and the Greeks and Romans both used them as food.

The development of the *Palinuride* seems to be very peculiar (Fig. 21). Claus observed in the ova of the Spiny Lobster (*Palinurus*) embryos with a completely segmented body, but wanting the appendages of the tail, abdomen, and last two segments of the middle body or thorax. They possess a single median and considerably compound eye; the inner antennæ are simple, and the outer are furnished with a small secondary branch; the jaws have no palpi or feelers. The jaw-feet of the third pair, like the two following pairs of feet, are divided into two branches of nearly equal length, whilst the last of the existing pairs of maxillipedes bear only an inconsiderable secondary branch. Coste is said to have bred the curious form of larva named *Phyllosoma* from the ova of *Palinurus*.

The Common Lobster (*Homarus vulgaris*, Fig. 22) prefers a rocky coast, and being somewhat of an epicure in his tastes, is tempted to such good purpose by the fishermen that as many as 25,000 live Lobsters are often delivered at Billingsgate in one day. If only as many are eaten in the whole of England as in London, this would be at the rate of 50,000 per day, or 18,250,000 annually. From March to August is the period of the greatest catch. Lobsters are sent alive packed in damp moss or heather from the south coast and Channel Islands, from Stornoway in the Island of Lewis, from

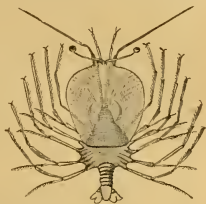


Fig. 21.—LARVA OF PALINURUS VULGARIS.

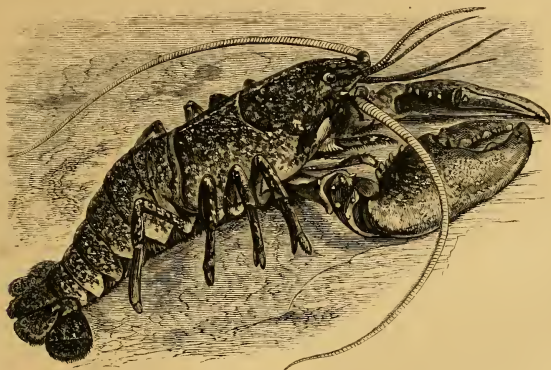


Fig. 22.—COMMON LOBSTER (*Homarus vulgaris*).

Ireland, Scotland, and the Orkneys. From Norway as many as 600,000 are received annually. Fishermen and salesmen are said to know the South Coast (English), Cornish, Scotch, Irish, or Norwegian Lobsters at sight, just as a cattle salesman knows a Hereford or Devon, a Scotch or Irish beast. The common Lobster weighs from eight to twelve pounds, but the great Lobster of the American coast (so largely imported in tins into England) weighs more than twice as much.

All the marine Macroura, or Sea Lobsters, undergo metamorphosis more or less considerable. Perhaps the changes passed through by the common Lobster present a less extraordinary variation

from the adult than in others of the long-tailed Crustacea. They are, however, sufficiently important to mention (Fig. 23). The eyes of the young Lobster are sessile, not mounted upon eye-stalks. The long antennæ are not seen, nor the beak or rostrum. The thoracic feet are rudimentary. The abdominal feet are entirely absent, as in the young Crab. At a later moult the jointed thoracic limbs are seen, and the antennæ begin to be developed. The hind body, or abdomen, is, however, still without appendages, and the eyes without eye-stalks. Still later these abdominal feet make their appearance.

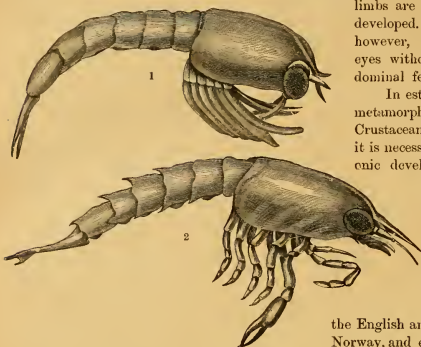


Fig. 23.—YOUNG LOBSTERS.
1, zoea just born; 2, after first moult.

nean. The body of this elegant species is long, and the segments extremely cylindrical in form; the cephalothorax is compressed at the sides. The great claws are long, slender, spiny, and ridged strongly down the centre; the rostrum is long and slender. The scale at the outer base of the antennæ is large. The eyes are large and prominent. The colour of this Lobster is much paler than that of *Homarus*, and there are bands of darker colour on the body-rings. There is only one species known.

The Common River Cray-fish (*Astacus fluviatilis*), a fresh-water genus, was separated by Milne-Edwards from the Lobsters, and may be readily known from others by the rostrum or beak having a small tooth on each side. Its carapace is granulated, and the telson, or median plate of the tail, is divided half-way up by a transverse joint across it, as are also the outer side-lobes of the tail. The outer antennæ have the second and third joints roundish, and covered by a broad and movable scale, which is narrowed towards each extremity, and pointed. The last joint or ring of the thorax is movable, whereas in the common Lobster the last thoracic ring is firmly adherent to the rest. The exopodite of the antennæ is reduced to a mere scale. All the abdominal appendages are well developed in both sexes, and in the males the two anterior pairs are somewhat like those of the male of *Homarus*, but less modified.

In estimating the greater or less extent of metamorphosis undergone by the young of any Crustacean in its passage to the adult animal, it is necessary also to take account of its embryonic development, for many species, both of the *Podophthalmia* (or stalk-eyed) and *Edriophthalmia* (or sessile-eyed) Crustacea undergo these larval changes in the egg, whilst others (as *Asellus* and *Mysis*) do so in the incubatory pouch of the mother.

The Norway Lobster (*Nephrops norvegicus*, Fig. 24) occurs on both the English and French coast, as well as on that of Norway, and extends as far south as the Mediterra-

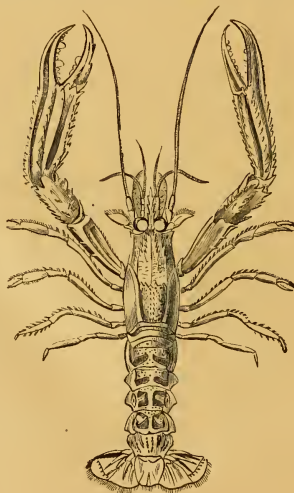


Fig. 24.—NORWAY LOBSTER (*Nephrops norvegicus*).

According to Huxley, the principal difference is to be observed in the gills, of which there are twenty on each side, sixteen belonging to the limbs and four fully-developed gills attached to the side of the thorax. Six of the former he calls *podobranchiæ*, or foot-gills, because they are attached to the *protopodite*, or first foot-joint, the other ten *arthrobranchiæ*, or joint-branchiæ, because their origin is on the joint of the leg where it unites with the thorax; lastly, the four on the sides are called by him *pleurobranchiæ*, because they spring from the part of the thoracic somite or body-ring known as the *pleuron*, or side piece, or *epimeral* portion of the segment.

The River Cray-fish (*Potamobius astacus*) is largely caught, and when fresh boiled is a dish not to be despised. It is largely imported into London for garnishing dishes with. The writer has with a friend taken over 900 River Cray-fish in the Thames and Severn Canal in Gloucestershire in a single evening between eight and twelve, with a series of simple scale-like nets, baited with liver.

The Cray-fish is one of those forms which is peculiarly interesting to the zoologist, as, according to the experiments of Ratke, it passes through its earlier metamorphosis in the egg, a circumstance which led Prof. Westwood in 1835 to doubt the correctness of Vaughan Thompson's discoveries as to the series of changes which the young of most species of Crustacea undergo after they quit the egg.

The most remarkable thing with regard to the genus is that, notwithstanding its inability to survive in salt or even brackish water conditions, its geographical distribution is wider than that of any other living Crustacean. Thus we find that representative species of the *Astacus fluviatilis* (which it seems, according to Huxley and others, we shall have in future to call *Astacus torrentium*) exist over the whole of Europe, save Sweden and Norway and Scotland, and that four other species inhabit the rivers which drain into the Caspian and the Black Sea. Two others belong to Japan and to the basin of the Amur, which sheds its water into the Pacific. The *Astaci* occur again in the rivers of North America west of the Rocky Mountains flowing into the Pacific, and the *Cambari* on the eastern or Atlantic side. It is more wonderful still that, separated by a wide equatorial belt, *Parastacida*, or representative forms, occur in the Southern Hemisphere, in New Zealand, Australia, Madagascar, and South America. The biggest of the



Fig. 26.—EYE OF TRILOBITE.

a, the eye; g, the glabella; b, rostrum of the lens; greatly magnified.

These compound eyes existed far back in geological time, and may be seen most beautifully preserved in the heads of many Silurian Trilobites, notably in the genera *Eglina*, *Phacops* (Fig. 26), and *Dalmanina*, whilst *Pterygotus*, like *Limulus*, had both compound eyes and simple ocelli. The eyes are the most constant and persistent organs possessed by the Crustacea as a class; indeed, if we except certain parasitic Isopodous forms and the Cirripedia and Rhizocephala, we shall find that the faculty



Fig. 25.—STRUCTURE OF EYE OF LOBSTER.

1a, section of eye, showing the several layers (a-b) composing it; 1b, 4 lenses of the eye, greatly magnified; 1c, a single lens, from the cornea to the optic macula; 1d, part of the surface of the eye; and 1e, section of same.

Cray-fishes which attains a length of more than fifteen inches, being as large as a full-sized Lobster, belongs to the Murray River, South Australia. The strangest are the genus *Engæus* of Tasmania and the *Cambarus* of the United States, and *Parastacus pilimanus* from Brazil, which live habitually on land in burrows which they excavate in the soil. This is the only family of Macrourea known to me which quits the water for dry land. Its geological history is as long as its geographical distribution is wide, for its ancestry can carry back their lineage to *Pseudastacus pustulosus* and *Eryma modestiformis* in the Jurassic rocks of Solenhofen in Bavaria.

The eyes in the higher Crustacea, like those of insects, are exceedingly complex structures (Fig. 25), composed of a great number of separate lenses closely compacted together, each having its cornea, its crystalline cone or lens, its pigment, and its nerve-fibre connecting it with the optic nerve. They present every variation, however, between this compound eye in the Decapoda down to the simple eye spot in the Entomostraca, whilst in some forms, as in *Limulus*, both simple and compound eyes are present on the same head-shield.

of sight is peculiar to the whole class. Even in those exceptional cases in which the eyes are aborted, we find that in the earlier and larval stages of their existence the parasitic and sedentary forms possessed eyes, and it is only as the effect of a kind of retrograde metamorphosis which the animal undergoes that the organs of vision disappear in the adult.

"The Brown Shrimp" (*Crangon vulgaris*) seems peculiarly an estuarine form, being taken in large quantities in Morecambe Bay, Lancashire, the Lynn Wash on the Lincolnshire coast, the Thames from Gravesend to the sea, and in the estuary of the Seine, especially near Honfleur. It is of a drab colour, dotted over with brown spots, and it does not become red by boiling as most other Crustaceans do. Its greatest length is two inches and a half (Fig. 27).

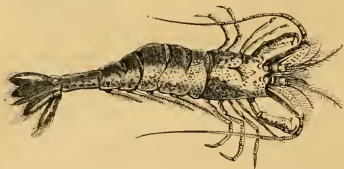


Fig. 27.—COMMON BROWN SHRIMP (*Crangon vulgaris*).

The absence of the prominent serrated beak or rostrum, so marked a character in all the *Palaemonidae* (Prawns and Shrimps proper), at once enables the collector to separate the *Crangonidae* therefrom. The chela of the fore hand are present in *Palaemon* but absent in *Crangon*, in which the fixed thumb is rudimentary.

An interesting little shrimp-like Crustacean, named *Alpheus*, which occurs only rarely off the English coast, but is abundant on the shores of Guernsey, Herin, and other of the Channel Islands, and one species in particular of which, the *Alpheus ruber*, is of a bright pink or salmon colour, has one claw of the first pair much more largely developed than the other, whilst the second pair are weak, slender, and many-jointed. This character in the second pair of legs is also observable in the genus *Nika*, closely allied to *Alpheus*.

All the members of this family (*Alpheidae*) are remarkable for the loud clicking noise which they habitually emit. It does not seem certain whether this sound, which is always accompanied by a sudden opening of the great claw to the fullest extent, is produced by impact of the heavy movable joint of the chela against the fixed ramus or by the forcible withdrawal of the huge stopper-like tooth from its pit in the penultimate joint of the claw. (Wood-Mason.) Col. Stuart Wortley remarks, "Keeping them as I do in an aquarium, it is startling sometimes in the evening to hear the loud snap produced by sharply striking together the two claws on the larger leg."

Palaemon serratus, the Common Prawn (Fig. 28), which is so well known as a favourite and delicate article of food, is found in vast numbers on the south coast of England. It appears from various accounts that it approaches the shore in its young state, and multitudes of them are taken in shrimpnets and sold as Shrimps. At



Fig. 28.—COMMON PRAWN (*Palaemon serratus*).

Bognor the fishermen consider them, when young, as a distinct species, and assert that, at certain seasons, they drive the true Prawns from their ordinary place of resort. The probability is that, at the season when the young ones have arrived at a certain size, they separate themselves from the older ones, which at that period of the year retire farther from the shore. At Poole the young ones of this species were commonly found associated with two other species of *Palaemon*, and the three are ordinarily sold there under the name of "Cup Shrimps," being measured in small cups instead of being sold by tale, as they are when larger. When of middle size

they still retain the name of Shrimps at that place, and are only called "Prawns" when they acquire larger dimensions.

Calocaris macandrea (Bell). This little Crustacean, which is found living at a depth of nearly two hundred fathoms, is fossorial in its habits, burrowing in sandy mud. Its eyes are quite rudimentary, being destitute both of pigment and cornea. Many Crustaceans obtained from great depths in the Swiss lakes prove to be blind. This is also the case with several species of Crustacea met with in the great Mammoth Cave and in the caverns of Carniola and Adelsberg.

Dr. A. S. Packard has described a Cray-fish, named *Cambarus pellucidus*, an Amphipod (*Niphargus stygius*), and two Isopods (*Titanethes albus* and *Cercidolea stygia*), from the Mammoth Cave, Kentucky, all of which are blind. "The eyes," says Dr. Packard, "in *Cambarus*, are rudimentary in the adult, but are larger in the young. This is evidence that the embryo develops like those of other species, and that the inheritance of blindness is probably due to causes first acting on the adults and transmitted to their young until the production of offspring that become blind becomes a habit."

Both *Niphargus* and *Crangonyx*, two forms of *Gammaridae*, have been obtained in England from wells and pumps in the Chalk and Oolite formations. They are wholly or partially blind.

CHAPTER III.

CRUSTACEA (concluded).

STOMAPODA—*Squilla*—*Mysis*—ISOPODA—*Bathynomus*—*Tanais*—The "Gribble"—*Asellus*—*Areturus*—*Sphaeroma*—Parasitic Forms—AMPHIPODA—The "Sand-hopper"—*Orchestia* and other Forms—Aberrant Amphipods—XIPHOSE—King Crabs—Character—Habits—CRYPTERIDA—TRILORITA—PHYLLOPODA—Character—CLADOCERA—OSTRACODA—COPEPODA—Parasitic Forms—CIRRIPEDIA—RHIZOCEPHALA—BALANIDE—LEPADIDE—Barnacles.

ORDER II.—STOMAPODA (MOUTH-FOOTED).

IN the STOMAPODA we find a considerable divergence from the DECAPODA already noticed. Taking *Squilla* as an example, the segments are much less coalesced than in the Lobster. Those bearing the eyes and antennules are readily separated from the front of the head, and are not covered by the carapace, which only conceals eight segments, whereas in the Lobster it extends over fourteen. The gills are no longer attached to the thoracic appendages, and enclosed in a branchial chamber formed by the head-shield, but they are transferred from the thoracic limbs to the abdominal swimming-feet, and are free and uncovered.* The first thoracic appendages are developed into a pair of robust claws, the terminal joint being furnished with a row of long and sharp re-curved teeth, which can be doubled back upon the penultimate joint, which has a groove to receive it like a pocket-comb. Armed with these two innocent-looking toilet requisites, *Squilla* goes about seeking whom he may devour.

In another genus belonging to this order (*Mysis*, or the "Opossum Shrimp," Fig. 30) special branchiæ seem to be absent, their duty being performed by the series of flabelliform appendages attached to the pedipalps, or thoracic feet, certain of which are modified in the female to form a "pouch," or marsupium, in which the eggs are protected and the young retained whilst passing through their earlier stages of existence.

These Opossum Shrimps are frequently met with in countless myriads towards the surface of the Greenland Sea, and, small though they be, they form the chief part of the food of the Common Whale (*Balaena mysticetus*), by which such a quantity of fat is accumulated. It seems at first sight incredible that so large an animal can be supported on so slender a repast, but, as in eating White-bait, numbers must count, and doubtless the Whale devours many hundreds of thousands at each mouthful.

* Hence they might aptly be termed *naked-gilled* Crustacea.

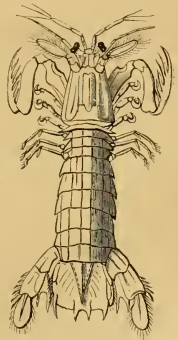


Fig. 29.—*SQUILLA* MANTIS.

From the stalk-eyed *Podophthalmia* we pass to the sessile-eyed *Edriophthalmia*, Crustaceans in which (with few exceptions) the eyes are fixed immediately on the surface of the head. As in the higher forms, the eyes are compound, consisting in the young of some ten or twelve lenses only, but



Fig. 30.—OROSOMUS SHRIMP (*Mysis chamroleon*).

in the adult of as many as from sixty to eighty. The head-shield in the Crab and Lobster encroaches so far upon the body-segments as frequently to conceal them, whereas in the EDRIOPHTHALMIA the head-shield only covers the seven first, or head rings, the seven thoracic segments being well developed in both divisions and the seven abdominal also in the Amphipoda, but in the Isopoda they are mostly coalesced together. The body in the Amphipods is compressed at the sides, whereas in the Isopods it is mostly broad and flattened in shape. Thus the Isopods and Amphipods form two very natural groups, which are comparable to the Crabs and Lobsters, the Isopods resembling the former and the Amphipods the latter in shape.

SECOND LEGION.—EDRIOPHTHALMIA.

ORDER III.—ISOPODA (EQUAL-FOOTED).

The ISOPODA are so named in allusion to the general conformity in size and function of the seven pairs of legs, the two foremost pairs of which in the AMPHIPODA are equivalent to the two outer pairs of jaw-feet in higher Crustacea.

In the DECAPODA, STOMAPODA, and AMPHIPODA, the branchiæ (in each case) are attached to the base of the legs. In the *Isopoda*, on the contrary, the posterior (abdominal) appendages are converted into special organs of respiration, in the form of leaf-like appendages. The heart is also near the tail. The body is composed of seven segments, generally nearly equal in size. To these, in the normal Isopods, seven pairs of nearly uniform legs are attached, either fitted for walking, swimming, or as powerful hook-like organs which enable them to adhere firmly to the fishes upon which many of them are parasitic.

One group of Isopods, the *Oniscide*, familiar to us in gardens under the name of the Common Wood Louse, are all air-breathers—not residing in water, but in damp situations—breathing air, which, however, it is necessary should be saturated with moisture. Several of the species which inhabit caves are destitute of eyes, e.g., *Titanethes albus*, from the Mammoth Cave, Kentucky. The Great Sea-Slater (*Lygia oceanica*) is common on the British coasts, running with agility, and folding up, so as to feign death, when attacked.

One of these, found in some gardens and woods, the *Armadillo* (also named the “Pill Bug” in America), from the perfect way in which the segments roll together, forcibly reminds one of the fossil genus *Illæmus barriensis*, a Trilobite found in the Upper Silurian at Barr, Staffordshire.

Prof. Alexander Agassiz, aided by the United States Coast Survey, has carried on extensive deep-sea dredging operations in the American seas, particularly exploring the bed of the Gulf Stream and the Straits of Florida, between the south point of Florida and the Island of Cuba. Among other Crustacean treasures obtained was a gigantic Isopod, dredged from a depth of 955 fathoms, on the north-east of the bank of Yucatan, and north of Tortugas. This Isopod has been named *Bathynomus giganteus* (Fig 31) by Alphonse Milne-Edwards. It measures nine inches in length by

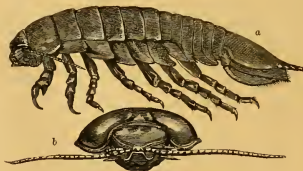


Fig. 31.—GIGANTIC ISOPOD (*Bathynomus*).
a, side view; b, front view of head.

four inches in breadth, and far exceeds any other living Isopodous Crustacean in dimensions. The gills or branchiæ, which in ordinary Isopods are simple leaf-like appendages, formed out of the modified abdominal feet, in *Bathynomus* consist of a highly complex arrangement of tufts of filaments supported on tubular peduncles covered by a series of opercular plates. Notwithstanding the vast

depth from which *Bathynomus* was obtained, the eyes are greatly developed, each being made up of about 4,000 square facets, and instead of being placed on the upper surface of the head, as in all known wandering *Cymothoidæ*, they are placed below the frontal border of the head at the base of the antennæ. Alphonse Milne-Edwards places *Bathynomus* in a new family of the division *Cymothoidæ*, named *Cymothoidæ branchifera*.

In *Tanais* (Fig. 32)—an aberrant form of Isopod—the first pair of legs are converted into chela, the six other pairs being simple, as in other Isopods. This peculiarity, and the confluence of the head with the first segments of the body, give it a very Macrouran aspect. In some the eyes are prominent, and almost pedunculated. This group also presents many points of affinity with the AMPHIPODA.

To the Isopodous division belongs the *Limnoria terebrans*, or the "Gribble," as it is commonly called by fishermen. It is a most destructive creature, attacking all woodwork below tide-mark, the only wood which it cannot destroy being teak. Although its ravages had gone on for centuries, it was only in 1811 that it was discovered and described by Dr. Leach.

The *Asellus aquaticus* is a very abundant form, inhabiting fresh-water ponds and ditches. The eggs and the young are retained in the pouch of the mother for about six weeks; probably half this period elapses before the young quits the egg. *Asellus* does not exceed six lines in length, and little more than half a line in breadth. It feeds upon vegetable matter exclusively. The leaves of the beech in decay are preferred, and in the parts of the pond where these are most abundant, there the *Asellus* is most numerous. The animal does not generally swim, it runs freely and expeditiously over the decaying leaves.

In *Arcturus* the young are carried by the parent in rows upon the long joints of its antennæ, the mother remaining in a nearly erect position clinging to a branch of some zoophyte or seaweed, along which she can walk by means of her hind feet. Until the discovery of *Bathynomus giganteus* by Agassiz (a form belonging to the *Cymothoidæ*), the *Idoteidæ* were supposed to contain representatives of the largest known Isopods, some of which measure about four inches in length. The hinder segments are welded together so as to form a long caudal shield, beneath which are two plates covering the branchiæ.

The genus *Sphaeroma*, the members of which are vegetable feeders, are also found guilty of destroying timber. When molested or alarmed, they roll themselves up into a ball. This genus and its allies offer many points of analogy, if not of affinity, with the extinct *Trilobites*.

Several species among the Water Breathers are parasitic, often on members of their own class. Thus in *Bopyrus* (Fig. 33, A) the female (which is, six times as large as the male) is parasitic within the branchial chamber of the Common Prawn, and out of six Prawns, it is no uncommon thing to

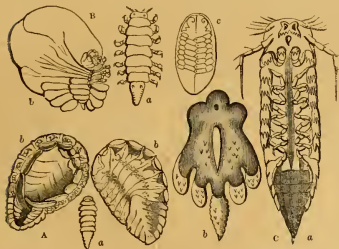


Fig. 33.—PARASITIC ISOPODS: BOPYRUS (A), PHRYXUS (B), CRYPTOTHYRINA (C).
aa, males; bb, females; c, larvae.

find one or more with this parasite distorting the carapace of the Prawn on one side. When the Prawn moults his shell, the *Bopyrus* manages to retain its situation, and re-appears with the new shell of the Prawn accommodating itself to the form of the *Bopyrus*. *Pagurus*, *Galathea*, *Callinassa*, *Porcellana*, *Palaemon*, and *Hippolyte*, all have these parasitical Crustacea in their branchial chamber. Another genus (*Phryxus*, Fig. 33, B) attaches itself beneath the tail of the Prawn, and we have taken it also from beneath the abdomen of the Common Shore Crab at Torquay. It is more curious still to note a parasitic Isopod, the female of which occupies the cavity within



Fig. 32.—TANAIS, A REMARKABLE ISOPOD.
A, the flabelliform appendage under the carapace in the rudimentary branchial chamber.

the shell of the living *Balanus balanoides*. A second species, also referred to the genus *Cryptothyris* (Fig. 33, c), is found resident within the body of another Cirripede (*Peltogaster*), which itself is parasitic on the tail of a Crab (*Portunus* or *Carcinus*). Those belonging to the genus *Ega* have all the feet furnished with a robust curved finger, sharp at the tip for seizing and holding on to fishes, as the Codfish, Whiting, &c., to the exterior of which they adhere. The *Eurydice pulchra*, common in the River Dee in Cheshire, will actually fasten upon bathers if they remain quiet in the water, adhering to the skin even after they emerge from the river.

ORDER IV.—AMPHIPODA.

In the AMPHIPODA the head is small, representing only the first seven cephalic rings, the seven thoracic and the seven abdominal being nearly equally well developed. The eyes are sessile or fixed, the body-rings are compressed laterally, as in the Lobster, and they possess both swimming and walking legs—indeed, we might add, leaping ones also, for many of them pass much of their time in this mode of progression on the shore. The first and second pairs of appendages become modified, in the male, into strong claspers, by the greater development of the hand and the movable character of the terminal joint, whilst the last pair of limbs are converted into leaping legs, like those of the Grasshopper. The gills are attached to the thoracic feet, as is also the incubatory pouch of the female. The heart lies beneath the dorsal surface of the body. To this division belongs the well-known "Sand-hopper" (the *Talitrus locusta* of Linnæus), one of the most abundant forms

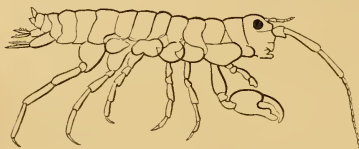


Fig. 34.—AMPHIPOD (*Orchestia darwini*). MALE.

everywhere around Britain, living between high and low water-mark, where it feeds on decaying garbage, both animal and vegetable, existing in myriads on some of the sandy shores. They never enter the water, but yet seem to require a certain amount of moisture to enable their branchiæ to perform their function. They burrow under moist seaweed and in damp sand. The young *Talitrus* usually remains with the parent for some time after they attain to maturity.

Another genus (*Orchestia*) also lives out of the sea, choosing moist places, but not burrowing as *Talitrus* does. On the British coast *Orchestia* lives within reach of the sea-spray, but some species in the Southern Hemisphere live many miles inland, choosing terrestrial plants for their abode. They are sometimes found at 1,500 feet above the sea-level (Fig. 34).

Salicitor lives along the sea-margin, making tracks upon the sandy shore, which, when in after years they have become hardened into sandstone, form puzzles for the paleontologist, who finds it sometimes difficult to decide whether they are worm-tracks or impressions of plants.

Blind species of *Niphargus* and *Crangonyx* are found inhabiting subterranean fresh waters in wells in the Chalk and Oolitic rocks of various parts of England and Europe. One species of *Niphargus* inhabits the hot springs of Italy.

The *Chelura terebrans* is one of the most injurious xylophagous Crustaceans known. It is commonly found associated with another wood-borer, the *Limnoria lignorum* (the Gribble), an Isopod, which, though smaller, is even more prolific than *Chelura*. The excavations made by *Chelura* are larger and more rapidly executed than those of *Limnoria*.

In all these forms an extreme degree of maternal solicitude seems to be developed, which exhibits itself not only in carrying the young, after hatching and brooding over them like a hen over her chickens, but in *Podocerus* the parent builds a nest in which the young are nurtured and protected, more after the manner of young birds than of such comparatively lowly-organised forms as Crustacea.

The LEMODIPODA form (according to Spence Bate and J. O. Westwood) an aberrant group of AMPHIPODS. The coxal joint of all the legs is fused with the body, and the tail is reduced to a rudimentary condition.

The popular name of Spectre, or Skeleton Shrimp, seems very appropriate to *Caprella* (Fig. 35). It lives amidst seaweeds and zoophytes, and is very active, scrambling from branch to branch.

"Their usual mode of progression is compared by Fabricius, Goodsir, and Gosse, to that of the larvæ of the Geometric Moths. They sometimes walk in this way for a considerable time, and then suddenly stop, remaining perfectly motionless, not even moving their antennæ. They seldom attempt to swim, and will, when placed in the water, independently of anything to rest upon, generally drop to the bottom." Like all the lower Crustacea, the *Caprella* cast their skins often. Before the process commences, the animal lies for a time to all appearance dead.

The Skeleton Shrimp carries its ova in an incubatory pouch, which is developed when required. "It consists of four plates, two attached to the third and two to the fourth segment of the body, arising upon the under surface and the inside of the branchiæ. As soon as the young are old enough to enjoy a separate state of existence they quit the protection of the pouch in which they have been nurtured, and, passing out, climb, gipsy-like, to the back of their mother, where they are seen holding on in every conceivable attitude. In the British Museum is preserved a specimen of an exotic species in which death has not separated the parent from her offspring. They may be seen attached, as if climbing from the incubatory pouch to the back of the parent."



Fig. 35.—THE SPECTRE, OR SKELETON SHRIMP (*Caprella*).

THIRD LEGION.—MEROSTOMATA.

ORDER V.—XIPHOSURA (KING CRABS).

The *Merostomata*, or "thigh-mouthed Crustacea," are represented to-day by the Horseshoe Crabs of America (Fig. 36) and the King Crabs of the China Seas (Fig. 37). There is only one living genus (*Limulus*), but it is found as far back in time as the Lower Secondary rocks, whilst forms, differing

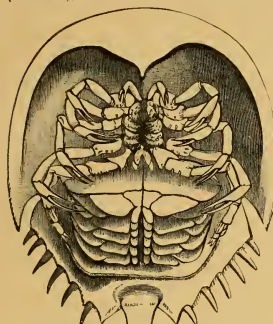


Fig. 36.—THE HORSESHOE CRAB (*Limulus polyphemus*), UNDER SURFACE SHOWING JAWS.

but little from those now existing, occur pretty numerous in the Coal Measures of England and America, and one is found so far back as the Upper Silurian formation. The soft parts are encased within a double shield-shaped shell divided into two parts, the first representing the head and the second the thorax and abdomen. The eyes are fixed on the anterior surface of the head-shield, beneath which are the walking limbs. The abdomen, however, is quite rudimentary, being partly represented by the posterior portion of the hind or thoracic shield, and partly by the long ensiform tail-spine. Under the hinder shield the leaf-like gills are placed. But in the larvæ we find the body-segments free and unanchylosed, and the tail-spine undeveloped, thus bearing out the characters common to the class, and connecting the living *Limulus* of to-day with its far-off ancestors in the Coal and Silurian periods. The limbs are all attached to the head, and correspond to the antennæ and the jaw-feet of the Crab and Lobster. They are, however, called upon to fulfil the double office of jaws and legs, which they do most

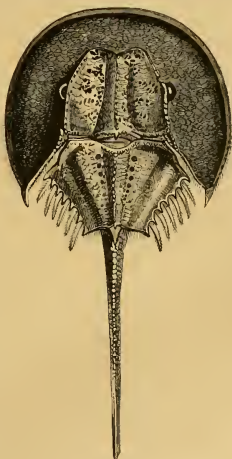


Fig. 37.—THE KING CRAB (*Limulus moluccanus*).

effectually. All the feet (save the little pair in front of the mouth) act as jaws, and they all have nippers or pincers at their extremities. The limbs of the thorax are converted into broad plates covering the ovaries and gills, and we find the last pair of feet are furnished with brooms with which to keep these delicate organs clean. Its eyes are placed upon the upper and anterior surface of the great shield-shaped cuirass or carapace, and it is furnished both with compound eyes, which resemble those of a Trilobite in form and position, being placed on each side of the head-shield, and also with a pair of larval ocelli or simple eyes placed just in the front of the head-shield.

Dr. S. Lockwood writes—"The King Crab delights in moderately deep water, from two to six fathoms. It is emphatically a burrowing animal, living literally in the mud, into which it scoops and gouges its way with great facility. The anterior edge of its enormous cephalic shield is not unlike in form to a cheese-cutter. The upper shell of the animal is composed of three parts—the forward shield, which is greatly larger than the posterior shield, and the long bayonet-shaped spine or tail. In the burrowing operation the forward edge of the anterior shield is pressed downward, and shoved forward, the two shields being inflected, and the sharp point of the tail presenting the fulcrum as it pierces the mud, while underneath the feet are incessantly active, scratching up and pushing out the earth on both sides. There is a singular economy of force in this excavating action, for the alternate doubling up or inflecting, and straightening out of the two carapaces, with the pushing purchase exerted by the tail, accomplish both digging and subterranean progression. The *Limulus* is carnivorous, its food being the soft nereids or sea-worms. The King Crab has six pairs of feet; the extreme anterior pair are called antennæ, being greatly shorter than the others. Of the four pairs between this pair and the last pair, the basal joint of each limb is flattened and smooth on each side, as though they were a series of plates intended to work upon each other. The external edge of each is rounded, and bevelled like a carpenter's chisel. Thus these flattened haunches lie against each other, their rounded edges directed backward at a considerable angle. The bevelled edges of these projections are covered with very sharp incurved spines, overhanging and pointing into the oral aperture, for it is between these five pairs of spine-clad haunches that the creature's mouth is situated. These, then, are the true jaws of the animal's mouth, and as there are five pairs of these manducatory joints, the creature's mouth is set in a line between ten joints. These spiny teeth have, by their articulation, an amount of mobility in their little pits which is eminently serviceable. Of these chewing teeth an individual can scarcely have less than one hundred and fifty."

It is extremely interesting to notice the occurrence at the present day of two living species of *Limulus*, one confined to the Moluccas and to the coast of China, the other to the eastern shores of North America, having continuous land separating them from each other from Tierra del Fuego to the Strait of Magellan. It speaks of the great antiquity of this genus, which has survived vast changes in the present configuration of land and sea, more even than is involved by the subsidence of the Panama Isthmus.

ORDER VI.—EURYPTERIDA* (EXTINCT).

ORDER VII.—TRILOBITA† (EXTINCT).

The sixth and seventh orders—the *Eurypterida* and the *Trilobita*—are both extinct, and have not been found, even in a fossil state, in any rock of younger age than the Carboniferous Limestone.

The *Eurypterida* are nearly related to the King Crabs, but the body-segments are distinct, not sclerled together, as in *Limulus*; but in both *Limulus* and *Eurypterus* the limbs serve the double office of jaws and feet, being masticating organs at one end and clawed feet at the other.

The Trilobites form one of the oldest groups of fossils known. Superficially, they closely resemble the living Isopods; but they have often more, and sometimes fewer, than seven free segments between the head and tail—a number nearly constant among the Isopods.

The appendages, too, of the Trilobites appear to have been quite different from those of Isopods.

* Greek, *eurus*, broad, and *pteron*, a wing (broad-wing), in allusion to the feet and to certain parts of *Pterygotus*, supposed by Louis Agassiz to have belonged to scaly fishes.

† Greek, *trilobos*, three-lobed, so named because all the segments of the body are corrugated, like a piece of iron or zinc roofing, into three arches.

FOURTH LEGION.—BRANCHIOPODA.

ORDER VIII.—PHYLLOPODA (LEAF-FOOTED).

The BRANCHIOPODA, or Gill-footed Crustacea, form the first division of the ENTOMOSTRACA, or "Shelled Insects," so called because most of its members are more or less entirely invested in a shelly envelope.

They are all aquatic, the greater part having a shell composed of two parts or valves, in which they are more or less completely enclosed, or in the form of a buckler, which envelops a large part of the animal. Their gills are attached to their feet, or to their jaw-feet. Like the higher class of Crustacea, they moult their shell and skin frequently.

Of the shield-bearing form of PHYLLOPODA (Fig. 38), the fresh-water *Apus* may serve as a good example. The eyes are placed on the dorsal surface of the carapace, and are nearly united. The antennæ are short and simple; the first pair of feet are very long and branching; these are followed by about sixty pairs of branchial feet. The thorax and abdomen are nearly cylindrical, and are composed of about thirty articulations, terminated by two long, many-jointed tail-spines.

Apus affords a good example of a form in which the mere vegetative repetition of parts is carried to an extreme distance beyond the normal number of body-rings so characteristic of the Crustacean class. Probably *Apus* has more articulations to its appendages and body than any other Crustacean. Schäffer tabulated them, and found they numbered 1,802,604; Latreille puts them down at not less than 2,000,000.

In *Nebalia*, the marine type, the head-shield is more arched, covering the body as in a bivalved shell. The eyes are pedunculated, and placed beneath the carapace. The number of segments is not excessive.

Otho Fabricius says that "the female carries her eggs beneath the thorax during the whole winter; these begin to hatch in April, and appear in May, when they are very lively, and adhere to the mother. The adult is not very active. On our coast they are found under stones, lying on mud amongst hollows of rocks."

The genus *Estheria* deserves to be especially mentioned on account of its wide distribution at the present day, and also because it has a very long past geological history. Its oval, bivalved shell has often been mistaken for that of a mollusc.

In *Cheirocephalus* and *Artemia* the shelly shield is altogether wanting, and their elegant movements in the water can be freely observed. The former inhabits fresh water; the latter is marine.

ORDER IX.—CLADOCERA.

In the CLADOCERA* the body, save the head, which is projecting, is entirely enclosed within a carapace, formed by the two valves of the shell. The eye is single and very large; the four to six pairs of feet are branchiform, the two large pairs of antennæ serving as organs of locomotion. Of this order, the Common *Daphnia pulex* (Fig. 39) of fresh waters is the best example we can take, not only on account of its abundance, but also because it has formed the subject of numerous memoirs by Professor Leydig and others. So plentiful are they in some ponds as to impart a blood-red hue to the water frequented by them. In order to apprehend the wonderful fecundity of this and allied genera, it is necessary to realise that a *Daphnia*, under favourable circumstances of temperature, may have three broods a month, or even a greater number, some of the larger species having as many as forty or fifty eggs at one brood!

* At particular seasons the *Daphnia* may be found with a dark opaque substance on the back of

* Greek, *klados*, a branch, and *keras*, a horn; hence branching-horned, in allusion to their antennæ.

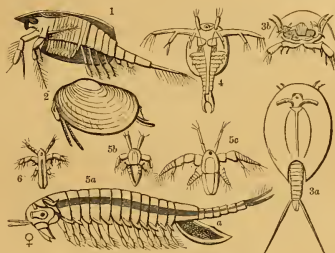


Fig. 38.—PHYLLOPODA.

1, *Nebalia bipex* (shell partly removed); 2, *Estheria*, sp.; 3, *Lepidurus augasi*—a, dorsal aspect, b, ventral aspect; 4, Larva of *Apus canaliculatus*; 5, *Branchipus* (*Cheirocephalus*) *stagnalis*—a, adult female, b, c, larvæ; 6, Larva of *Artemia salina*.

the shell. This is what Muller calls the ephippium, from the resemblance it bears to a saddle. But though he describes it well, he does not give any opinion upon the cause or use of the formation. Straus, however, has proved it to be an inner bivalved case or shell, containing two eggs, destined, he says, for perpetuating the species in the spring: these eggs resisting the cold of winter, which proves fatal to the perfect animal."

FIFTH LEGION.—LOPHYROPODA.

The LOPHYROPODA, or stiff Hair-footed Crustacea, form the second division of the *Entomostraca*. The same simple structure is repeated as in the BRANCHIOPODA, with but slight variations in the organs of locomotion.

ORDER X.—OSTRACODA.

In the fresh-water *Cypris* and the salt-water *Cythere* the body is enclosed in a bivalved shell. Dr. Baird says of *Cypris*:—"When the ponds and ditches in which they live dry up in summer, they bury themselves in the mud, and thus preserve their lives as long as the mud retains any moisture, becoming as active as ever when the rain falls and again overflows their habitation. After long-continued drought, however, when the mud becomes very dry and hard, they perish; but the eggs do not perish with the parents, for they can be hatched in four days after being placed in water. These little creatures seem to be very lively in their native element, being almost constantly in motion, either swimming about rapidly by the action of their antennæ, or walking upon the plants and other solid bodies floating in the water."

The *Cythere* are minute marine Crustacea, and are met with in pools amongst the rocks along the coast. "These animals," says Dr. Baird, "have never been seen to swim, invariably walking among the branches and leaves of the *Confervæ* or *Fuci*, &c., where they delight to dwell. When shaken out from their hiding-places into a bottle or tumbler of water, they may be seen to fall in gyrations to the bottom, without ever attempting to dart through the watery element, as is the case with the *Cyprides*. Upon reaching the bottom, they open their shells and creep along the surface of the glass, but when touched they immediately again withdraw themselves into their shell, and remain motionless. Their inability to swim is, no doubt, owing to the want of the pencils of long hairs or filaments which adorn the superior and inferior antennæ of the *Cyprides*."

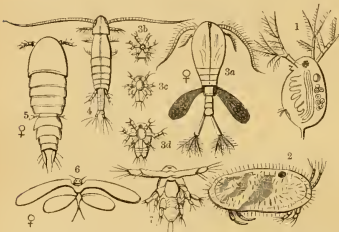


Fig. 39.—FORMS OF CLADOCERA, OSTRACODA, AND COPEPODA.

1, *Daphnia pulex*, fresh water; 2, *Candona hiepidia*, fresh water; 3, *Cyclops quadricornis*, fresh water—a, adult female, b, c, d, larvæ; 4, *Cetochilus septentrionalis*, Firth of Forth; 5, *Sapphirina ovalata*, Atlantic; 6, *Nicoboradactylus*, parasitic in gills of lobster; 7, Nauplius stage of Copepod.

forms serve as oars to propel the animal through the water. How great must be the numerical strength of the species in these lower forms, when *Cetochilus* so minute can yet colour the sea for miles in extent, and furnish abundant food for so large a mammal as the Whale!

The various species of the genus *Cyclops* abound in inland waters all over the world, being essentially fresh-water animals, in a few cases only inhabiting slightly brackish water. They are amongst the most abundant of all the individuals of the order. The young stages of *Cyclops* have been named as distinct species, the same animal having been honoured with four or five different titles between birth and maturity. The full-grown female is often of considerable size. The eggs are carried in pouches, and are not dependent on the mother, but will come to maturity if separated from her. The eggs vary in number, old individuals laying upwards of forty. It has been calculated that in one year a female would become the progenitor of 4,442,189,120 young, so that the abundance

ORDER XI.—COPEPODA.

In the fresh-water *Cyclops* and the marine *Cetochilus* (Fig. 39) the head and thorax are covered by a shield, and the posterior abdominal segments are distinctly seen. The long antennæ in the latter

in which they are met with is not strange, notwithstanding their many enemies. The *Cyclops* feeds both on animal and vegetable matter.

The *Cetochirus*, or "whale-food," is one of the small Entomostraca, known to the fishermen of the Firth of Forth by the name of *maïdre*, on which the Herring and many fine species of Salmonide live almost exclusively. These small Copepods abound in such quantities as to obscure the water; immense shoals of Cod-fishes are seen swimming lazily about, devouring them in large numbers. Shoals of Herrings are also seen pursuing them with great agility.

The Parasitic COPEPODA may be divided into two groups. The first comprises the free-swimming genera, in which both the male and female retain their organs of locomotion in the adult state, and can change their habitat whenever needful. This division includes the fresh-water *Argulus* and the marine *Caligus*. The second division includes the fixed parasites, in which the females, when adult, lose their locomotory appendages, and become fixed, deriving their nourishment by a true suctorial mouth, armed with jaws for piercing the tissues of the fishes and other animals upon which they are parasitic; the males, however, remaining free.

"The *Argulus* in England is found upon various fresh-water fishes. In the neighbourhood of London it is most commonly to be met with upon the Stickleback, but it has been taken also upon the Carp and the Roach; and in other places it has been found upon the Trout, the Pike, the Perch, and even upon the tadpole of the Frog."

Professor Dana described a species taken in the Mill River, near Whitneyville, into which the tide runs, thus showing that *Argulus* can live in brackish water.

Loefling states that the part where *Argulus foliaceus* is chiefly found is within the gills, or immediately outside; and Dana and Herrick inform us that their *Argulus catostomi* was always found within the branchial cavities, but when the fish itself was immersed in fresh water, the parasite forsook the gills, and, after swimming about some time, would often attach itself to the anterior part of the body. The number of eggs deposited by one *Argulus* is very considerable. Dr. Baird says as many as 400 have been laid by *A. foliaceus*, and 1,500 and upwards by *Argulus catostomi*.

Caligus and other allied genera are called *fish-lice*, and are observed to infest the Cod and the Salmon; they are marine Crustacea. Dana says the *Caligi* are most numerous on half-grown fish, and occur on the head and different parts of the body, but never within the gill-covers or under the scales. Dr. Baird says of the European species that they live under the scales, and are often found on the parietes of the mouth and branchial cavities. "When disturbed, they move with rapidity over the fish, and either backward or forward with nearly equal facility. In swimming, their motion is equally rapid. They thus travel over the fish at will, and, we do not doubt, occasionally leave one fish for another."

Both sexes frequently occur on the same fish, though the females are the more abundant. The sizes of the individuals vary, but the adult male often is two-thirds of an inch in length. The females are seldom more than half an inch long, and are always smaller than the males.

"The *Caligi* live several hours on the body of the Cod taken from the water, but generally die soon after the death of the fish. When taken from the fish and confined, they exhibit a strong inclination to leave the water. These animals, like the Cod on which they live, require a low temperature, and have been observed to swim, with scarcely diminished activity, in water that was freezing. In some instances, when the water had evidently reached a temperature below 32° Fahr. without congelation, they have been rendered torpid, and apparently dead; but on bringing them into a room not above 45° Fahr., they have soon resumed their usual activity."

The *Caligi* change their skin, as well as the other Entomostraca, but little is yet known of the process. The young, when first hatched, closely resemble the young *Cyclops*, and, like them, undergo a series of moults, or changes of skin, before they become perfectly developed.

Nicothoe astaci, a very small species, of a rosy colour, attaches itself to the gills of the common Lobster (Fig. 39).

The LERNEADÆ (fixed parasites) fasten themselves to the eyes and various parts of the bodies of fishes in different ways—some by means of the foot-jaws alone, others by a series of horns proceeding from the side of the head, and others, again, by two long appendages, which spring from the upper part of the thorax, which unite at the tip, and form a sort of round button.

"In general, it is only the adult female of the *Lerneæ* that we are in the habit of observing; and in an animal whose organs of motion and perception for the most part are merely rudimentary, and whose existence is strictly stationary, the manner of life must be very simple. Immovably fixed upon the fish which serves it for food, its existence depending upon the life of its host, it requires neither feet to transport it from place to place, nor eyes to guide it in search of fresh abodes. In fact, the whole of its active existence consists in the two operations of taking food and propagating its species. We find them in all instances deeply fixed in the tissue of the parts upon which they have taken up their habitation, and often so deeply lodged that little else but the oviferous tubes are visible externally. These small parasites have been found adhering to the gills of the Dory, the Sole, the Gurnard, and the Salmon, to the fins and gills of the Cod, Haddock, and Whiting, and to the sides of the Carp, Bream, and Roach."

Scoresby, the Arctic voyager, mentions a species of *Lernæopoda* found adhering to the eye of a Greenland Shark; the arm-like appendages were buried in the cornea, to the depth of nearly a fourth of their length. The Sharks thus attacked seem to be rendered blind by their pigny assailants. "The sailors," says Captain Scoresby, "imagine this Shark is blind, because it pays not the least attention to the presence of a man, and is, indeed, so apparently stupid, that it never draws back when a blow is aimed at it with a knife or lance."

The "Eye-sucker" (*Lernæonema spratta*) is found fixed by the snout to the eye of the Sprat.

Conrad Gesner, in his "*Historia Animalium*," 1558, describes the structure and appearance of this parasite, "because," he says, "few people know what this parasite is, as it is very small, seldom to be seen, except at the time of the rising of the dog-star, and then not on many fishes, but only on the Tunny, Sword-fish, and occasionally the Dolphin (and not even on every individual). It adheres so firmly that it cannot be removed without tearing it. It sucks the blood of the fish, like as a leech does, till it falls off through very fulness, and then dies."

SIXTH LEGION.—CIRRIPEDIA.*

ORDER XII.—RHIZOCEPHALA (ROOT-HEADED CRUSTACEA).

In the RHIZOCEPHALA the young are free, and resemble young larval Cirripedia, or the adult *Cypris* and *Candona* (Fig. 39). The adult (female) is destitute of all appendages, and attaches itself by means of root-like prolongations from the head to the body of the host upon or within which it is found.

Thus the female of *Entoniscus* resides within the body of a species of *Porcellana*, lying in a thin-walled sac between the liver, intestine, and heart, and is destitute of eyes or antennæ. The thorax has become an irregular iuarticulate sac, beset with enormous brood-lamine; the long vermiform and extremely mobile abdomen has sword-shaped legs; and swelling out above it in a glandular form, as if in a hernial sac, the heart lies at the base of the first segment.

The young in this singular parasite closely resemble those of *Bopyrus* and *Cryptothyria*.

The genera *Sacculina* and *Peltoaster* are usually found parasitic on the abdomen of the Hermit Crab. The animal appears as a small ovoid or kidney-shaped mass, attached by the head, whilst its roots penetrate deeply into the liver of the Hermit Crab.

The only manifestations of life which these most retrogressively metamorphosed Crustaceans present are powerful contractions of the roots, and alternate expansion and contraction of the body, causing water to flow into the brood-cavity, to be again expelled through a wide orifice.

In 1858 Lilljeborg found what he deemed to be a female *Peltoaster* with an egg-sac; but a careful dissection led to the discovery that another parasite of a higher order, namely, a *Cryptothyria*, had become parasitic upon the parasite. The most curious part of this super-parasitic history is that the roots of *Sacculina* and *Peltoaster* seem constantly to be made use of by two parasitic Isopods—namely, a *Bopyrus* and the *Cryptoniscus planaroides*. These take up their abode beneath the *Sacculina*, and cause it to die away by intercepting the nourishment conveyed by the roots; the roots, however, continue to grow, even without the *Sacculina*, and frequently attain extraordinary extension, especially when a *Bopyrus* obtains its nourishment from them (Fritz Müller).

Let gardeners take a hint from this, and graft some new fruit upon the mistletoe bough.

* Latin, *cirrus*, a curl, and *pes*, a foot; hence, curl-footed.

ORDER XIII.—BALANIDÆ.* ORDER XIV.—LEPADIDÆ.†

Thanks to Charles Darwin, Vaughan Thompson, Goodsir, and Bate, the CIRRIPEDIA, one of the most aberrant groups, have now a place among the Crustacea (Figs. 40, 41). The two great divisions of BALANIDÆ and LEPADIDÆ represent the condition of the adult female, or hermaphrodite; the larvæ, resembling the young of *Cyclops* and *Cypris*, being free-swimming forms, and undergoing a series of metamorphosis, as do some of the highest Crustacea.

"Almost every one," says Darwin, "who has walked over a rocky shore, knows that the Barnacle, or 'acorn-shell,' is an irregular cone, formed generally of six compartments, with an orifice at the top, closed by a neatly-fitted, movable lid, or operculum. Within this shell the animal's body is lodged, and through a slit in the lid it has the power of protruding six pairs of articulated cirri, or legs, and of securing by their means any prey brought by the waters within their reach. The basis is firmly cemented to the surface of attachment. The whole shell, basis, and operculum consists of the first three segments of the head, modified into a singularly constructed carapace, which encloses the mouth and rest of the body. The anterior extremity of the shell is situated in the centre of the basis, where, indeed, by due care, the antennæ of the pupa may be always detected; the posterior extremity is directed vertically upwards."

When the period has arrived at which the young *Balanus* or *Lepas* shall assume the adult characters, it attaches itself by its antennæ, which are modified as cement-ducts, and by which it becomes fixed to a suitable body, organic or otherwise, and secretes a shell.

In the one group (*Balanidæ*) the base is fixed and immovable, save the opercular valves; in the other (*Lepadidæ*) the shell is supported on a peduncle more or less movable.

"The Barnacle begins life in a form exactly like that of a young Entomostracous Crustacean, with a broad carapace, a single eye, two pairs of antennæ, three pairs of jointed, branched, and well-bristled legs, and a forked tail. It casts off its skin twice, undergoing, especially at the second moult, a considerable change of figure. At the third moult it has assumed almost the form of *Cypris* or *Cythere*, being enclosed in a bivalve shell, in which the front of the head, with the antennæ, is greatly developed, equalling in bulk all the rest of the body. The single eye has become two, which are very large, and attached to the outer arms of two bent processes, like the letters **U U**, which are seen within the thorax (Fig. 41, c).

"In this stage the little animal searches about for some suitable spot for permanent residence—a ship's bottom, a piece of floating timber, the back of a Whale or Turtle, or the solid rock. When its selection is made, the two antennæ, which project from the shell, pour out a glutinous gum or cement, which hardens in water and firmly attaches them. Henceforth the animal is a fixture, glued by the front of the head to its support. Another moult now takes place; the bivalve shell is thrown off, with the great eyes and their **U**-like processes, and the little Cirriped is seen in its true form. It is now in effect a Stomapod Crustacean, attached by its antennæ, the head greatly lengthened (in *Lepas*, &c.), the carapace composed of several pieces or valves, the legs modified into cirri, and made to execute their grasping movement backwards instead of forwards, and the whole abdomen obliterated, or reduced to an inconspicuous rudiment."—(Gosse: "Manual Marine Zoology.")

Professor Ryner Jones observes that the food of the Cirripedia consists of various small animals, and nothing can be more effective or beautiful than the manner in which it obtains its prey. "Its food is caught in the water around them by a mechanism at once simple and elegant. Any one who watches the movements of a living Cirriped will at once see that its arms, with their appended cirri,

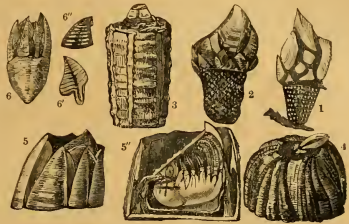


Fig. 40.—CIRRIPEDIA.

1, *Scutellum rostratum*, Philippines; 2, *Pollicipes cornuopsis*, European seas; 3, *Tubicolle trachealis*, attached to whales; 4, *Coronula diadema*, attached to whales; 5, *Balanus tintinnabulum*, Atlantic; 5'', section of same showing animal in shell; 6, *Acornis sulcata*, found in living sponges; 6'', opercular valves of same.

* Latin, *balanus*, an acorn.† Greek, *lepas*, a limpet.

are in perpetual movement, being alternately thrown out and retracted with great rapidity; and that, when fully expanded, the plumose and flexible stems form an exquisitely beautiful apparatus, admirably adapted to entangle any nutritious atoms or minute living creatures that may happen to be present in the circumscribed space over which this singular casting-net is thrown, and drag them down into the vicinity of the mouth, where, being seized by the jaws, they are crushed and prepared for digestion. No sense but that of touch is required for the success of this singular mode of fishing; and the delicacy with which the tentacles perceive the slightest contact of a foreign body shows that they are eminently sensible to tactile impressions."

The process of exuviation common to the class Crustacea cannot take place with the shell in the CIRRIPIEDIA, but the delicate skin of the articulated *cirri* (whence their name "Curl-footed"), the tunic lining the sac, and the integuments of the whole body are regularly moulted. All the Cirripedia grow rapidly; and Darwin says, "in accordance with this rapid growth is the

frequency of periods of exuviation.

Mr. Thompson kept twenty specimens of *Balanus balanoides* alive, and on the twelfth day he found the twenty-first cast-off integument, showing that all had moulted once, and one individual twice within the period. This frequency of exuviation explains the astonishing masses of exuvia which Mr. Peach assures me he annually has observed off the coast of Cornwall; they are most abundant in April and May, but he has seen quantities also in September. He could easily, he tells me, have filled several quart-measures with them."

The only difference of the growth

of the shell in the Cirripeds and that of other Crustaceans is the new layers of thin shell which grow up or are deposited over the internal surface of the valves, the old shell adhering to the outside of the new one; the margins are added to slowly, but not continuously, instead of being formed at a single period.

"In the genus *Alcipe*, the whole of the external membranes are moulted, excepting the surface of attachment; but these Cirripeds live in cavities, which they form for themselves, and are thus protected."

"The most remarkable fact concerning the *peduncle* of *Lithotrya* is that the outer tunic, together with the calcareous scales with which it is covered, is moulted at each successive period of exuviation and growth. I demonstrated this fact in *L. dorsalis* and *L. truncata*, by removing the old tunic, and finding a new membrane with perfect calcified scales beneath; and as these two species are at the opposite extremes of the genus, no doubt this fact is common to the whole genus. I know of no other instance amongst Cirripedia in which *calcified* valves or scales are moulted. I am not certain that the whole skin of the peduncle is thrown off in a single piece, though it is almost certain in the case of the uppermost and lowest portions."

In viewing *Lepas* in comparison with other forms, it is necessary to treat it as attached by its head, its thoracic appendages serving as cirri, its abdominal segments being suppressed or undeveloped.

The Cirripedia extend over the whole world, and all the species are marine; some are parasitic on Whales, others on the Turtle, and many forms live floating about on ships and timber.

HENRY WOODWARD.

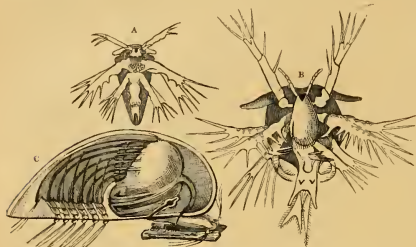


Fig. 41.—LARVAL FORMS OF CIRRIPIEDIA.

A, Nauplius of *Balanus*; B, Larva of *Chthamulus stellatus*; C, Larva of *Lepas australis*.

CONCLUDING REMARKS.

We have thus arrived at the conclusion of a necessarily very condensed sketch of the vast group of animals arranged by naturalists in the great division of the Arthropoda, a group which is certainly the most numerous in species, and probably also in individuals, of all the great primary sections into which the animal kingdom may be divided. A few additional words summing up the relations of the group as a whole may not, however, be out of place.

A consideration of the habits of the species and their relations to the world, at large seems to indicate that the primary function of the group in general is that of a natural police, acting sometimes openly in the sight of all, sometimes in a concealed fashion, which renders it difficult to realise the extent of their influence. Among the scavengers both of land and water the foremost place must certainly be assigned to Arthropods, numbers of which seem to be constantly on the watch for all those articles called by the French "immondices," the continued presence of which, either in the air or in the water, cannot fail to be either offensive or injurious to other living organisms. Excrementitious matters and putrefying or decaying animal and vegetable substances are thus rapidly got rid of and brought once more into the cycle of vitality, and in these useful operations thousands of species of insects of different orders, many mites, and a very large proportion of the class Crustacea, are perpetually engaged.

Of the rest, while there are some which seem to have no particular mission, the great majority may be regarded as acting more or less powerfully as checks upon the increase of other animals and plants, and this often in so direct a manner that our best examples of the system by which the numerical proportions of different kinds of organisms are maintained in the world are to be derived from the study of these creatures. The whole series of predaceous insects, the carnivorous Myriopods, and the great mass of the Arachnida, are most efficient agents in keeping down the development of their weaker fellows, while a host of plant-eating species, especially of insects, perform the same part for the vegetable kingdom. Parasitism, which is common throughout the three great classes of Arthropoda, and manifests itself in many very remarkable ways, plays a most important part in checking the increase of animals of many kinds, and, as we have seen, provides a peculiarly delicate means of regulation, seeing that under the influence of parasites the creature affected is able to perform its principal functions in the economy of nature, but is weakened or altogether destroyed when the time of reproduction arrives.

The action of the Arthropods in nature is in numerous cases greatly intensified by the important changes through which so many of them pass in the course of their life-history. Phenomena of more or less similar character certainly occur in other groups, but those extra-ovular changes which we dignify by the title of metamorphoses, and which in their extreme manifestations make one animal play the part of two, constitute a general characteristic of the Arthropoda, and have a most important bearing on their life-history. Of the metamorphosis we may distinguish two kinds in the Arthropoda generally. In the great majority of the types distinguishable in the group, we find what may be called a "direct" metamorphosis, that is to say, the young animal escapes from the egg in a form differing more or less from that of its parents, but destined to reach the mature form by simple growth and development of its parts with or without the addition of new parts as it advances in age, a mode of development which we recognise throughout the Crustacea, Arachnida, and Myriopoda, and in the whole of the lower (or hemimetabolous and ametabolous) insects. In the metabolous insects, or insects with a complete metamorphosis, we find another set of phenomena superadded, a more or less worm-like larva stage being intercalated between the egg and the perfect insect. The explanation of this seems to be furnished by the life-history of certain parasitic forms of Coleoptera, such as the Meloide and Stylopide, in which the insect when first hatched is a little six-legged creature presenting all the external characters of a larva destined to undergo direct development towards the perfect form, but subsequently giving origin to a soft, maggot-like larva, which would never be supposed to have any connection with its predecessor. It seems probable that, in the history of the class Insecta, a similar change, the traces of which are now preserved only in a few species, may have taken place in the course of development of certain forms, and that through these the whole series of insects with a complete metamorphosis may have

originated from hemimetabolous ancestors. However it was introduced into the life-history of the Insecta, this worm-like larval form is certainly their most important modification. As already indicated, it enables each individual to play two distinct parts in the economy of nature, and it is by its introduction alone that the internal parasitism, which is characteristic of so many families of insects, is rendered possible.

In some few insects, but much more strikingly in members of the classes Arachnida and Crustacea, parasitism superinduces a metamorphosis of another kind, which is commonly known as "retrograde metamorphosis," seeing that the adult parasite, instead of showing an advance upon the structure of the newly-hatched young, exhibits a marked degradation of type. This curious and interesting phenomenon is well shown in the numerous forms of parasitic Crustacea, such as the Lerneadæ and Rhizocephala, and especially in such parasitic Isopods as *Eutoniscus*, &c., the larvæ and males of which display true Crustacean characters, while the parasitic females are mere egg-sacs, which might very justifiably be taken for worms. The Cirripedia again exhibit another phase of what must be termed retrograde metamorphosis.

It will be seen, from the foregoing rapid sketch of the development of the Arthropoda, as also from various statements contained in the preceding description of the classes and orders composing the group, that whatever indications of alliances outside the group are presented by its members are all in the direction of animals now included under the great division of the Vermes. In the general description of the characters of the class Insecta, we took occasion to indicate that in former days the Arthropoda and Vermes, as then understood, were regarded as forming a single great division of the animal kingdom, the Annulosa, characterised by the ringed or segmented structure of the body displayed by its typical members, and we must confess to a lingering doubt whether such a grouping does not present a more philosophical idea of the relationships of these creatures than the one now generally adopted. Under any circumstances, it is among the Vermes that we must seek the nearest allies of the Arthropoda; or, in other words, to adopt the views of the illustrious Darwin, which, whether accepted as the expression of facts or not, must, as we have more than once stated, furnish the guiding principles in inquiries of this nature, the ancestors from which they were derived.

It would seem, from the investigations of Mr. Moseley and others upon the curious genus *Peripatus*, that the remarkable worm-like creatures forming it, which are so peculiar both in their organisation and in their geographical distribution, represent the surviving progeny of organisms directly uniting the Annelida (the highest class of Vermes) with the Myriopoda as we now know them. If this be the case, one line of descent is very plain. The group of Chilognathous Myriopods (such as *Julus*, &c.) would be easily derived from modified *Peripati*, and the transition from them to the Chilopoda presents no difficulties, even from the consideration of existing forms. The production of Myriopods must have taken place at a very early period of the world's geological history, as their remains have been detected in Devonian rocks in America. The production of six-legged larvæ by the Juliform Myriopods, if not inherited from the Peripatoid ancestor, may have been superinduced as a saving of material in the egg, and these larval forms lead directly to the truly ametabolous Thysanura, among which *Campodea* is regarded by Sir John Lubbock as approximately representing the lowest and earliest type of true insect, from which all the other multitudinous forms may have been derived by descent with modification, the Hemimetabola retaining the direct mode of metamorphosis as above described, starting from the *Campodea*-like larva and reaching the adult form by growth with addition of parts; the Metabola proceeding from the latter by the superaddition of a vermiform larva stage with its concomitant or resting pupa stages. In most cases the primitive larval form appears to have become suppressed in the metabolous insects, although it is still retained, as above mentioned, in *Melœ*, *Sitaris*, *Stylops*, and their allies.

With regard to the Crustacea and Arachnida, we get no information from this assumed line of descent, and the fact that the latter belong to the tracheate series of Arthropods renders the question of their origin rather puzzling. It would appear, however, that the primitive larval form of the Crustacea is the little creature described as a *Nauplius* (pp. 194-6), which is the first product of the egg in the majority of the lower types of the class, while in the highest groups the young animal is generally of the form originally described as a distinct genus under the name of *Zoëa* (pp. 194-6).

For a long time it was supposed that this constituted a positive distinction between the lower and higher Crustacea (some intermediate forms, Edriophthalmia, showing no larval forms at all), but the researches of Fritz Müller proved that in certain Shrimps (*Penæus*, pp. 194-6) the *Zoëa*-form was preceded by a *Nauplius*-form, thus furnishing analogous evidence to that existing in the case of insects, of the existence among Crustacea of a primitive and a superadded larva (*Nauplius* and *Zoëa*), of which the former had in many cases become suppressed.

If we consider the Crustacea to follow the same principle in their development as the Insecta, we must regard the *Nauplius*, or some Naupliiform creature, as the primitive form of the class from which all the rest have proceeded by descent with continual additions and modifications of parts; but it is hardly possible with our present knowledge to indicate the particular type of the Vermes from which, or from the larva of which, the primitive *Nauplius* could have originated. But the interesting fact becomes perfectly plain that as the *Peripatus* could have nothing to do with the origin of the Crustacea, the evolution of the Arthropod type must have taken place along, at least, two lines of descent of different origins, a view which was adopted by Prof. Balfour in his very valuable work on "Comparative Embryology." It is possible that the starting-point of the Crustacean line was from some organism pertaining or approximating to the group of creatures now known as Rotifera.

The Arachnida, through the curious little Tardigrada, which are generally considered to have Rotatorian affinities, may have originated from the same point as the Crustacea, but if so they must have diverged at an exceedingly early stage of the evolution and formed a branch of their own, gradually acquiring those characters which bring them apparently into affinity with the Insects and Myriopods. The character of the respiratory organs, which has been adopted for the division of the Arthropoda into two main groups of Tracheata and Crustacea is evidently of no consequence in connection with this question of descent, seeing that it is quite clear, from the analogy of *Peripatus* and the Earth Worms, that throughout the Annulosa the principle on which the originally aquatic forms are adapted for aerial respiration consists in the substitution for the primitively exposed branchial organs of concealed cavitary organs, the arrangements by which the blood is brought in contact with the respiratory medium being strictly homologous in both cases. The passage upward through the Mites to the Spiders and Scorpions may then easily be conceived. The parasitic forms, such as the Linguatulina, originated by a process of retrograde metamorphosis; while the singular group of the Pantopoda, with their remarkable larvæ, would seem to have remained from an early period at a very low stage of development.*

Another group, which we have here placed with the Crustacea, is regarded by some naturalists as belonging truly to the Arachnida. This is the order Xiphosura, including of living forms only the few species of King Crabs or Horseshoe Crabs, the structural relations of which to the Scorpions would seem to be very close, and certainly raise a difficult problem, and one which is rendered still more interesting by the fact that, according to the researches of Dr. Jules Barrois, a Limuloid or King Crab-like stage occurs in the development within the egg of certain true Spiders. For the present this and many other such questions must, however, remain open. In all biological problems relating to the past developmental history of the organic world we must for a long time yet expect to come continually upon obscure and puzzling points, which only a more extended knowledge of minute details can clear up.

* Professor Balfour (Comp. Embryol., vol. i., p. 448) says of the Pycnogonida:—"The six-legged larva has none of the characteristic features of the Nauplius, except the possession of the same number of appendages;" but he places the group among those of doubtful affinities.

W. S. DALLAS.
HENRY WOODWARD

GRAND DIVISION, OR TYPE.—VERMES (THE WORMS).

CHAPTER 1.

THE RINGED WORMS.

The Various Sorts and Conditions of Worms—Classification—ANNELIDA, *THE RINGED WORMS*—OLIGOCHÆTA—The Earth Worm—Characters—Structural Peculiarities—Habits—Other Species—The Naide—The Tubificide—POLYCHÆTA—Marine Worms—Characters—ERRANTIA—APHRODITIDÆ—Sea Mice—Scale Backs—The Eunicide—The Sæo—Habits—The Nereide—The White-rag Worm—The Syllide—The Phyllodoce—THE TUBE-MAKERS—Characters—The Lug Worm—Habits—"Baiters" on the Search—CIRRATULIDÆ—Characters—The Terebellide—Their Larvæ—The Serpulide—The Fan Sabella—Serpula Vermicularis—Its Array of Hooks—The Protule and other Tube-makers—THE LEECHES—Appearance—Action of Sucker—Characters—Different Kinds—The Horse Leech—The Glutton Aulostome.

THE commonly received opinion about Worms is, that they are very unimportant animals which lead very obscure lives, and that there are not many of them. But a little observation proves the fallacy of the greater part of the popular idea. The common Earth Worm is seen in numbers early in the morning, and on every lawn the birds may be noticed pulling them out of their holes and swallowing them. Boys who require Worms for fish-bait soon become impressed with their numbers, for every dig of the spade brings up one or more. By the sea-side, Lob Worms are forked out of the sand by fishermen, in abundance. In chemists' shops one used to see quantities of leeches in pots, and that they are Worms is pretty evident. Sometimes in out-of-the-way localities, the shop-windows of worm-doctors are to be seen filled with bottles containing flat, long, limp-looking things, called Tape Worms; and every nurse knows that children suffer from Thread Worms. The farmer loses his sheep from a curious head affection, and on examining them he finds peculiar Worms. Grouse and Chickens die from the gapes, and it is a Worm that does it. Pigs suffer from a Worm in their muscles, and fishes have others in their bodies and eyes, and man has them sometimes in his blood. Finally, in the marine aquarium the loveliest fan-shaped expansions, coming out of tubes fixed to the rock, are the breathing organs of a Worm. In numbers, probably the Worms surpass all other things except the Infusoria; in habits they are most varied, and they are correspondingly diversely fashioned. In some Worms there is boldness and a power of roaming for purposes of attack, and then they are well provided with structures and organs; but in others there is only a very passive existence, and there is an extraordinary absence of structures, senses, and of many organs. Parasitism within animals is the lot of many Worms, and some lead a part of their life in one animal, and another in a second unwilling host, or they may live free at some time or other. So varied are the shapes and so inconstant are many of the structures of the Worms, that it is by no means easy to give a definition which shall include them all. Not only peculiar structures, but also the absence of certain structures known to exist in other animals, have to be considered. Thus it is found that an animal does not exactly correspond with one of the articulate groups; and another resembles in certain points, but not in all, an Infusorian. They are then placed with the Vermes, because of the existence of certain fundamental structures. Again, many of the Vermes are parasitic, and their structures have been most curiously modified to meet their method of life—or, rather, their methods—for most pass through very remarkable life-cycles.

The Vermes do not move by means of articulated limbs, and the body is not jointed like that of a Crustacean or Insect. But whatever may be the shape of the body, it is composed of incomplete segments, the majority of which are similar, and is more or less ringed outside. The segments are provided with offensive and locomotive organs on both sides, and usually with a special excretory organ opening from within. There is a water system communicating with a cavity in the body surrounding the digestive system, and with the outside, called the perivisceral cavity. The digestive system may be well developed, but in some parasites it is absent, and their nutrition takes place by absorption through the outside of the body. There is a kind of circulatory system present in some, and also special organs of respiration, such as branchial tufts; but many are without them. The nervous system may consist of a cord around the œsophagus, with ganglia above and below, and a ganglionic cord along the ventral surface within; or the vestiges of the system may be very scanty. Sense organs, such as eyes, may exist in a rudimentary condition, and also organs of feeling. The digestive organs vary greatly in their development; and the stomach and intestines, fairly developed in some, are wanting in others. The movements of the body are not produced by jointed

limbs, but by the segments, assisted or not by lateral projections and cilia. Although there is great diversity in form, the organs and structures of the body are, to a large extent, the same on both sides, and hence there is bilateral symmetry.

The Vermes are divided into five classes—the Annelida, the Gephyrea, the Rotifera, the Nemathelmintha, and the Plathelmintha—or the True-ringed Worms, the Marine Worms, the Wheel Animalcules, the Ribbon Worms, and the Flat Worms.

CLASS ANNELIDA (THE RINGED WORMS).

SUB-CLASS CHÆTOPODA.

These Worms have bristles upon the segments, either on processes called false feet (parapodia), or in depressions in the tissues of the skin. Presenting great differences in structure, they are divided into two large orders, in one of which (the Oligochaeta) the bristles are comparatively few, and never on parapodia: there are no tentacles, cirri, or branchiae, and the sexes are combined; these Worms, moreover, do not undergo metamorphosis. The second order (the Polychæta) are Marine Worms, with separate sexes, undergoing metamorphosis, and they have numerous bristles carried on parapodia, and also tentacles, cirri, and branchiae.

ORDER OLIGOCHÆTA.

These are long Worms found in earth, mud, and fresh water, which are known by their negative, rather than by their positive zoological characters. They have no structures on the sides which may be called "feet," and they have not any armature like jaws, in relation to the pharynx. They are without tentacles, and do not possess cirri or branchiae. The sexes are combined, and there is no metamorphosis. Being Annelida, they have segments, and there are bristles projecting from them. There are two sub-orders of these sparsely-bristled Worms, and in the first (the Terrestrial, or *Oligochaeta terricola*) the Earth Worm is the type.

The Earth Worm, or Dew Worm,* is such a familiar object that it is only necessary to remark on some of its peculiarities. The head is a long, obtuse cone; the first segment is usually lobe-like; it overhangs the wide circular mouth, and is more or less retractile within the second ring. The segments of the body are narrow, and furnished with minute bristles, some of which, more or less hooked, are called spinets, and are retractile. There are no eyes, jaws, or branchiae. On the segment behind the first are two furrows, often joined by a cross one; and farther back is a smooth, glistening brown part, differing from the rest of the Worm in appearance: it is called the clitellus. The hinder part of the body is flatter and broadens out, and the anal segment is small, reddish, and has tumid projections. The genital pores are on the fifteenth ring. There may be from twenty-eight to thirty-two rings in front of the clitellus, which has six segments, and 106 behind it. In the skin and clitellus are organs for producing mucus, and it can be noticed that a red fluid circulates in an imperfect circulating vessel called the pseudo-hæmal system. The nervous system consists of central ganglia above the pharynx, cords connecting them around the pharynx with a long chain of nerves and ganglia, extending through the length of the body on the ventral wall of that cavity which environs the internal organs—the perivisceral.

The upper lip is slightly elongate, and covers the mouth, which leads to a muscular pharynx, ending within the body, at about the seventh segment; a narrow œsophagus is continued backwards to about the sixteenth. There are three pairs of pouches in the sides of the œsophagus, which contain



EARTH WORM.

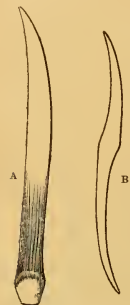
* *Lumbricus terrestris*.

a calcareous matter. This gullet widens into a sort of crop, which terminates in a thick and muscular gizzard. Then follows a single tube—the intestine—which is turned in, as it were, along its back, so that there is a longitudinal projection into the intestinal canal. The excretory or segmental organs are tubes which are much convoluted, and one is situated on each side of every segment except the first. Externally, it opens by a minute pore placed close to a pair of bristles or setæ; and internally it communicates with the perivisceral cavity by a wide, funnel-shaped ciliated aperture.

Each segment of the body has four double rows of minute setæ on it, which project slightly beyond the integument, and pass inwards into the tissues. A series of small apertures, or pores, one for each segment except the first, is on the back, in the median line, and they lead inwards to the perivisceral cavity; and upon the opposite side of the body are eight apertures for the reproductive organs. When an Earth Worm is in good health and clean, its thin, transparent, but dense outside skin shows a play of colours. Within this layer is a connective tissue with the meshes filled with a gelatinous substance, and still within is a thick layer of circular muscular bands, with pigment granules. A longitudinal layer of muscular fibres is internal to all the rest. So the outside of the Worm is muscular and membranous, and contains many cells for the secretion of mucus outside, and passages into the inside. Within are the viscera and the perivisceral cavity, and this is subdivided

by a tissue which passes inwards from the divisions between each pair of segments. Yet there is communication between each subdivision, and also between it and the outside, through the segmental organs. The short spinets, or curved setæ, project farther into the interior of the body than externally. The ends of each pair are close, but their origins within the body are wider apart; each is enclosed in a sac in which it is developed, and to which the muscles by which it is protruded are attached. There are eight setæ to a segment; one pair is not far from the middle line below, and the other pair are farther out on either side.

There is a colourless fluid with corpuscles in the perivisceral cavity, and the deep-red fluid already mentioned is found in a system of pseudo-hæmal vessels. These are longitudinal and transverse canals and branches, ramifying in all parts of the body except the outside skin. In the seven front segments the longitudinal vessels form a network, and behind it cross vessels are greatly developed, and form five to eight pairs of false hearts. They contract from the back towards the under side.



SPINE (A) AND SPINET
(B) OF LUMBRICUS
TERRESTRIS.

The Earth Worm is very widely distributed; and some of the species, for there are many, are found on continental and oceanic islands, yet they neither swim nor like salt. They are all nocturnal in their habits, and swallow earth, and digest any organic matters which may be in it, casting forth the residue in the form of cylindrical twists of sand or mud. Charles Darwin has shown that they are the great producers of good soil, and hence the term vegetable mould should rather be animal or worm mould. The Worm should therefore be cultivated rather than destroyed, and the only harm it can do is when it lives in the same pot as a flower, for then it abstracts the organic part of the mould which would be of use to the vegetable. Formerly Worms were much used in medicine. The Earth Worm lays its eggs in capsules at some depth in the soil during the spring, and they hatch in the summer, and the young are about an inch in length, and have no clitellus. Like many other Vermes, the Earth Worm has the power of reproducing lost parts, and of healing and growing when cut in half. Anglers use the common Earth Worm for Eels and Perch, but another species, the Brandling (*Lumbricus fetidus*), is the best for Trout. This is a reddish-brown Worm with alternate yellow and brown segments, and it has a tapering tail, and exudes a yellow pungent fluid when touched. A huge Worm occurs in Ceylon, called *Megascolex ceruleus*, and it is sometimes forty inches long, and is as thick as a finger. Its segments are surrounded by a complete circle of setæ. Dr. Baird described a species of this genus which had been found in a hot-bed in a garden in Wales, but probably it had been introduced accidentally.

There are many species of *Lumbricus* in England. In one, the front of the body is different

from the hinder part, *L. anatomicus*; one is greenish, and is found under stones in cattle fields, *L. viridis*; another is phosphorescent, and there is a pigmy form of the great Earth Worm.

The second sub-order is that of the water- and mud-inhabiting Oligochaeta—the *Oligochaeta limicola*. There are four families of them, and that of the Naidæ is the most important, *Nais proboscidea* being the type. These Naidæ have a head distinct from the body, and the first three or four segments have no bristles. The mouth is exactly terminal, and there is no overhanging lip as in the Earth Worm. Their body is much flattened, and the bristles are comparatively long, and there are two kinds of them on the segments, which are rather indistinct. The upper bristles are setæ, and are collected in small bundles, and the lower are spinets, which are forked at the tip; and with their aid the Worms creep actively, and even swim. They live on small animals and are oviparous. They are remarkable for their facility of multiplying by spontaneous division. This has been noticed in the typical species, whose individuals are about half an inch long, and are found about the roots of aquatic plants. Mr. Lewis noticed that the perfect Worm begins to grow a second head near the extremity of the body, and then other segments are developed, the tail, or final segment, being the identical tail of the mother, but pushed forward by the young segments, and now belonging to the child, and only vicariously to the mother. In this state, he adds, we have two Worms and one tail. In some other species the tail has finger-shaped processes which probably act as respiratory organs. One genus, *Aulophorus*, secretes a tube, which it carries about, and its upper bristles are hair-like, and the lower ones stiff. Some Naidæ have eyes, as in the instance of the type, but one species, which has finger-shaped projections (*Protoligitata*), has not any. The genus *Chaetogaster* has a cylindrical body, truncated in front, without eyes; and the mouth, which is terminal, is barbed underneath on the first segment. The bristles are in a single row on either side of the ventral aspect, but they are massed together in groups of four or five or more hooked setæ. They reproduce principally by a process of gemmation or budding, and form chains of four, eight, or sixteen individuals, and each has four segments including the head.

The genus *Lumbriculus*, which has a contractile vascular space to each segment, and no vascular network in the skin, has species living in fresh water, which are red or brown in colour, and have no clitellus.

The family Enchytraidæ may be typified by a Scottish species (*E. vermicularis*). This is a white, indistinctly segmented Worm, with the thirty to seventy segments armed with short spinets in four small fascicles or bundles. It lives in the soil under the bark of rotted trees or decaying leaves. There is a small white spot near the first third of the body. If this little Worm, which is found lying rolled up in a loose, spiral manner, be placed on one's hand, it wriggles much and soon dies. It cannot live except in moist places.

The family Tubificidæ contains numerous genera, with four rows of recurved setæ, which may be simple or forked, and the species have contractile vascular canals, besides the dorsal vessel. The reproductive organs are in the 9—11 segments. These Worms* live in water in cylindrical tubes of mud on the bottoms of streams, and their mouth segments are united, and often lengthened, and their skin is transparent and appears of a deep red colour in the water; the portion within the erect tube is pale straw colour. The dorsal vessel is distinctly seen beneath the skin, and the intestine also, which makes a twist at every segment. They are common in the mud of the Thames. This little Worm is gregarious, and when seen in clear water their movements, each half out of its tube, are interesting. They withdraw into their tubes on alarm, and do not come out again for some time. It is the tail end that projects and not the head. One of these red Worms lives in wet gravel, or sand, or brackish water;† and a very filiform species, which has a clitellus, lives between tide-marks;‡ and another lives as a parasite in the Mussel.

ORDER POLYCHÆTA.

These are highly-developed Marine Worms, and they have parapodia, or feet, on their sides, furnished with numerous bristles, as their name implies. They have also tentacles, cirri, and branchiæ. The young are not born like the parent, and undergo a metamorphosis. The sexes are usually separate. The Polychæta are divided into two sub-orders:—firstly, those which possess

* *Tubifex rivulorum*.

† *Tubifex lineata*.

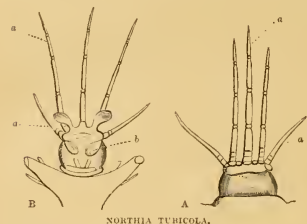
‡ *Clitellio arcuarius*.

well-developed foot organs, which lead a roaming life, the exceptions being very few, and which are carnivorous and predaceous—they are the Errantia: secondly, those which live in protecting tubular structures, and which have feebly developed feet, and are called the Tubicola.

In examining these many-bristled Worms it is advisable to employ certain descriptive terms. Thus, the first segment of the body is called the prostomium, and the mouth opens on it: the second is the peristomium. When the three front segments are united, or when they differ from those which come after, they are called the head or cephalic segments; but when this is not the case

the Worm is said to be acephalous. The head has various appendages according to the genera. Antennæ are soft filaments varying in number from one to five, and they arise directly from the head, are not retractile, and are usually jointed at the base. Sometimes palpi exist, and they are soft, entire, or jointed processes, arising from the sides of the mouth. The tentacles are soft, bristly, or thread-shaped, non-retractile processes, which arise from each side of the segments of the head in pairs, and spread laterally. They are often very long, and are contractile in the acephalous genera.

The mouth is underneath the head, and is a round or transverse opening to the gullet. It has usually a plain margin. In the acephalous genera

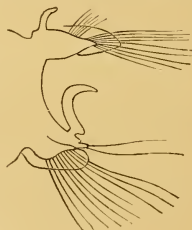


NORTHIA TUBICOLA.

A, cephalic segment; B, mouth, &c.; a, tentacular cirri; b, upper lip.

it is terminal, and has external tentacles, but there are no jaws, and in the cephalous it is nearly terminal and looks forward horizontally. It is almost always furnished with a proboscis in the cephalous tribes; that is to say, the oesophagus or gullet can be protruded. It consists of two segments, and can be put forth at pleasure by a process of turning inside out. It is often armed with horny jaws, in opposite pairs, or is roughened on the surface with horny prickles; or it may be covered with pimples, or be plain. The head is succeeded by the "thoracic segments," and in the cephalous genera there is but one of them. It is naked and has no appendages. But in the acephalous genera, and in some of the others, the thoracic segments are distinguished by peculiarities in their structures and appendages. They may be fleshy, and contain most important organs, and the branchiæ are often limited to them. The abdominal segments complete the body, vary in number, are alike, and lessen in size, the last being the anal. This has no setigerous feet, and no soft appendages; but more commonly a pair of soft filaments, called styles, project behind. The vent is terminal and central. The segments have appendages on either side, and the principal is a lobe, which is called the foot, or parapodium.

The so-called foot, or parapodium, is a pimple-shaped projection on either side of a segment. It supports the bristles, which are, as it were, sheathed by it, and it is a basis of attachment for the branchiæ, and soft, setaceous filaments, called cirri, resembling tentacles. The foot may be in one lobe, or there may be two lobes; one upper or dorsal: and the other, lower or ventral. These lobes, also called branches, are more or less apart, and when there is but one branch, or lobe, the foot is said to be uniramous, and when there are two, biramous. Taking the uniramous foot of one side of a segment of *Nephtys longisetosa* as an example, the upper and ventral lobes are seen to be wide apart, but to be connected. The bristles of the two lobes are long hair-like setæ; the cirri are two curved hooklets projecting downwards from each lobe, and besides these there is a kind of flap behind the bristles, which probably is a rudimentary branchia. The bristles are of four kinds in these Polychæta, the spine, which is subulate, straight and tapering from the base to the apex. It is placed in the midst of a bundle of bristles. The spinet is a hook or fork, and is only found in a few



FOOT OF NEPHTHYS.

genera. The bristles are either formed of one continuous piece or are jointed. They may be hair-like, setaceous, or slender, and tapering insensibly to the end, lanceolate or swollen. The branchiæ in the cephalous Worms are attached to the base of the foot, on the upper or dorsal side, and are either restricted to a certain number of segments, or they are found on all. They are either arborescent, combed on one side, flat, and veined, or they may be filamentary. At the base of the branchiæ, or in portions of the lateral trunks, are "hearts," the direction of the fluid being from behind forwards in the dorsal vessel, and the opposite in the ventral trunk. There are numerous branches to the trunks in most, but not in all, the Polychæta. No segmental organs—excretory—have been discovered in the majority of these Worms, but they do exist in some, as short ciliated canals opening on the parapodia or ventral surface, or as cavities with glandular walls. They may excrete a renal deposit, or may have to do with reproduction. The nervous system consists of a chain of ganglia, one pair for each segment, connected together by longitudinal and transverse bands which diverge below the cerebral ganglions and the succeeding pair, to allow of the passage of the œsophagus. The commissural bands differ in length in the many genera, and some fusion of the ganglia also occurs. An extensive series of nerves is given off to the viscera.

The general cavity of the body, the perivisceral, contains a fluid and colourless corpuscles, except in two genera; and this fluid is continuous with that of the parapodia, and their accessory structures, they being more or less hollow, and in relation to the perivisceral cavity. Cilia, and the movements of the body, produce the circulation of this fluid. Branchiæ are represented by ciliated spots on the dorsal side of the bases of the parapodia, or ciliated tubercles may arise from the spot, and it is within them that the cæca of the alimentary canal terminate. There may be filiform branchiæ or there may be branchial tufts. The pseudo-hæmal system may or may not be present, and when it is found, as, for instance, in the genera where tufted branchiæ exist, loops of the great vascular trunks enter them. These trunks are dorsal and ventral, connected by transverse branches, and may be rhythmically contractile. They are large, squamous, lobe-like, or tubercular. In many acephalous genera the branchiæ are placed in front, in tufts.

The cirri are simple, soft, tapered filaments, or papillary processes attached to the dorsal and ventral lobes, at or near the base. Their office appears to be tactile, and they may be considered as the tentacles of the body.

In the Polychæta the foot and its accessory structures are well developed on either side of certain segments. The group, as a rule, are cephalous, and their alimentary canal is almost always of the same length as the body, and extends without marked distinction into stomach, and convoluted intestine, from the mouth to the anus. In some genera, long cæca are given off from each side of the alimentary canal, and are sometimes much convoluted. The pharynx is muscular, and when turned out as a proboscis is in some instances as long as the body. There are papillæ on it, and, in some cases, horny teeth, which are carried and implanted in the muscular tissue. Eyes and auditory vesicles exist; the former are simple expansions of nerve embedded in pigment, and are usually on the prestomial segment; but in some genera they are on the segments and tentacles. Some species have them on the tail end, and the locomotion is then with the posterior part forwards. Otoliths have not been satisfactorily made out in the Errantia, but they have been discovered in the Lob Worm.

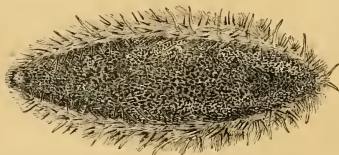
SUB-ORDER ERRANTIA.

The majority of these many-bristled Worms lead an active, predatory life; have a distinct head, carrying eyes, tentacles, and usually tentacular cirri. The body is not divided into different regions, and the highly-developed parapodia are used as oars. The gullet is probosciform and armed, and when the branchiæ exist, they are tufts or comb-shaped projections on the dorsal lobes of the feet. They swim freely, and only a few inhabit temporarily very thin membranous tubes. In some genera there are flap-shaped processes to the body, which are called elytra and flap-shaped branchiæ.

The Errantia are very numerous in individuals. There is a host of genera, and no less than twelve families, some of which are again subdivided.

THE FAMILY APHRODITIDÆ.

Of this family the very un-worm-like animal called the Sea Mouse,* with long bristles on its feet, which gives all the colours of the rainbow in the sunlight, and is common on the south coast of England, is a good example. It frequently attains the length of from eight to ten inches, and is of an oval shape. Its back is covered with numerous scales, or elytra, hidden under a covering of fine bristles. Another, called the Porcupine Sea Mouse,† has the scales visible, ranged in double series on the back. It is not so long as the Sea Mouse, nor is it as brilliant in the iridescence of its foot setæ. Found on the coasts, it, like its fellow, affords food for fish. The rough Scale-back‡ is one of the family, and is smaller than the species just noticed. It is of a brown colour, and underneath it is whitish. The back has twelve pairs of scales, which overlap in the middle line, and are hairy on the free

SEA MOUSE (*Aphrodita aculeata*).

edges. The Worm is thus covered with armour above, and the head is protected by the first pair. There are four small black eyes, three feelers, with knob at the end, and two palpi. The animal has twenty-five pairs of feet, and the setæ of their dorsal and ventral lobes are golden yellow. There are 7,230 setæ of exquisite structure, according to Dr. Baird, on the animal. Most of those scaled Worms move at a slow pace, but they can swim pretty quickly. The proboscis is long and strong,

and has filaments around the opening, and it leads to a short digestive apparatus. The species of *Lepidonotus* have horny curved jaws, and are carnivorous like the others. They live on living Invertebrata, and are cannibals also, and like most of the family frequent the region below low spring tides, and even live under stones on rocky shores at a less depth. Some live deeper, and a few burrow in the sand very easily. One of the species of Scale-back Worms is long and narrow, having seventy to one hundred and ten segments in the body. It has the scales, in pairs, forward, but the under part is naked, and the scales alternate, with dorsal cirri. This Scolopendrine Scale-back§ is four inches in length, and it frequently forms a tubular case of sand and pieces of shell for itself, which it agglutinates with a mucus secretion from its body.

This species belongs to a sub-family of the Aphroditidæ, and its congeners are found on the northern sea-coasts, the Australian, and Antarctic coasts, and in the Mediterranean Sea.

The Boa-shaped Sigalion|| is also a long narrow Worm with numerous pairs of elytra, which reach the end, and may amount to 140 pairs. The Worm is eight inches in length, and only a quarter of an inch in breadth. The feet are very numerous, and there are horny jaws. They live near low water-mark in the British and Mediterranean Seas.

Another family is that of the Amphinomidæ. They have no scales on the back, but an uninterrupted series of shrub-like branchiæ on each side of the body attached to nearly every segment. Most are found on the shores of warm and tropical countries, and the boatmen of Ascension Island wrongly consider the pricks of their setæ to be poisonous. The genus *Euphrosyne*, with an oval body made up of a few segments, which bear branchiæ in tufts, placed behind the feet, frequents the west and south of England, and lives down to about ten fathoms.

The family Euniciæ is distinguished by a long and numerous segmented body, and a distinct and projecting head. The proboscis is short, and is furnished with several pairs of jaws placed one over the other, and approximated beneath, so as to rest on a kind of under lip of the same texture. The body is usually long and slender, and the number of tentacles varies. The first and second segments have no feet, and the others have one-lobed feet which carry dorsal and ventral cirri and comb-shaped filaments or branchiæ on the dorsal side. The genus *Eunice* has foreign species more than four feet long, and one found on the English coast is two feet long, and as thick as a man's finger, the body consisting of 300 segments.¶ It is of a dark-green colour, and the

* *Aphrodita aculeata*.† *Aphrodite hystrix*.‡ *Lepidonotus squamatus*.§ *Polynoe scolopendrina*.|| *Sigalion boa*.¶ *Eunice sanguinea*.

branchiæ are intensely red. But the tints depend much on the situation where the Worm lives. When they are found in clefts of rocks, living in a kind of gallery which they construct, they are rich in their tints, and are iridescent. On the other hand, if they are taken amongst sea-weeds, or from off a muddy bottom, they are dull in colour.

The Sao,* one of this family, lives in a tube which it constructs for itself, and which presents the exact appearance of a quill pen. It is of a horny substance, about four inches long, smooth, transparent, and somewhat flexible. Living in soft mud, the animal immerses one end of this tube, and protrudes the other end to some distance. The habits of this Worm have been described with great accuracy by Dr. Johnston, whose words we quote :—

“One unceasing object of its life is the capture of prey. For this end it must protrude the anterior portion of the body beyond its tube, and raise itself above the surface of the mud, and remain in this position on watch. To enable the Worm to do this with ease is, I conjecture, the office of the forceps-like bristles of the feet; with their ends, it may hook itself to the rim of the tube, and thus obtain a support without the waste of muscular power. A long watch is thus rendered less irksome, while at the same time the capacity to seize upon a passing prey is increased. The prey caught, analogy leads us to conclude that the Worm will instantly retreat and sink within its tube, where it can feed without disturbance or fear. But as the entry and passages are narrow and unyielding, it seems to follow that the prey should be held by the mouth alone, when in the act of being dragged within the tube, and hence surely the reason that the mouth has been furnished with the hard tubercles to the lips; for when pulled together and put in contact, they must give a firmer grip and hold than could otherwise be taken. The use of the tube is to protect the body from the pressure of the soft mud in which it stands immersed. When the tube is overset, or cast out by the waves or accident, the Worm leaves it, and becomes in its turn exposed to enemies. To protect itself from these, while a new tube is being secreted, nature has amply furnished the Sao with a series of bristling lances on each side. These arms are of exquisite make, very fine and very sharp; and those of the upper bundle have their points bent and inclined towards those of the lower bundle, which are likewise bent to meet them. Arms like these will inflict wounds on the tiny assailants of the Sao, sufficiently painful to repulse them, and a lethal wound is not necessary.”

The Eunicidæ, as a rule, undergo metamorphoses; but a few of them are born in the shape of their parents and in the viviparous manner. The larvæ, in the first instance, are ciliated, and there are one or more special ciliated bands in particular regions of the body, and assisting in locomotion. Some genera have bands at both ends, or at one extremity only. The head of the perfect worm gradually develops, and then the tail out of the larval form, and the ciliated bands are lost. The segments between the head and tail are formed, as it were, by a budding.

The family Nereidæ have long slender bodies with two anal cirri, and the head is flat and four-eyed. There are two small middle and two large outer feelers at each side of the mouth. The pharynx is protrusible, and there are two large horizontally-moving jaws armed with denticles. The parapodia are double, and have sharp spines, but no hair-like bristles. The genus *Nereis* is very common, and nearly every stone that is turned over near the sea-water edge sets some moving. Gosse describes the Pearly Nereis† a common species, as having a warm brown-coloured upper surface, but the beautiful flashes of iridescent blue that play on it in the changing light, and the exquisite pearly opalescence of the delicate pink beneath, are so conspicuous as to have secured it the title of pearly. The great dorsal vessel is a dark red line along the back. *Nereis pelagica* is another species, which attains six inches in length, and is as thick as a quill. The body



NERVOUS SYSTEM OF NEREIS.
(After Gegenbaur).

a, upper, b inferior ganglion of pharynx; c, ventral trunk; d, nerves of mouth, e, of antennæ; f, eyes placed on superior ganglion of esophagus; g, lateral nerves.

* *Northia tubicola*.

† *Nereis margaritacea*.

is brilliant in colour, with flesh and iridescent blue tints. It is a great wanderer, burrowing often in the mud in brackish water marshes and pure sea-water shores. In its larval state, just after the tentacles are developed, it is phosphorescent, and may be seen on the shells of oysters.

The White-rag Worm*, or Lurg, is common on the British shores, and varies from six to ten inches in length, being about three-tenths of an inch wide. It is of a beautiful pearly lustre, and the feet are much developed, and increase gradually in size from the head to about the middle of the body, and then decrease. It lives in the sand, burrowing into it by means of its strong

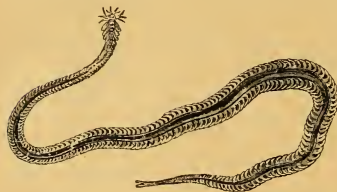


LURG (*Nephtys caeca*).

proboscis, and holding itself fixed by its setigerous feet. When swimming it uses the feet as oars, and moves very quickly through the water. Fresh water soon produces convulsions and death.

A Worm called the Prolific Syllist† belongs to the family Syllidae. It has the head distinctly seen, and the tentacles are pointed, and the creature has eyes. Dr. Johnston observed that this Syllis is more studious to divide than to unite. When it divides, the posterior half grows a head before it is separated, so that the Worm looks like two individuals joined together, the one holding on to the hinder extremity of the other. Quatrefages has shown that although the two halves are alike when separated, yet they have very different internal structures and gifts. The anterior half continues to eat as before, and conducts itself as an independent creature; but the other individual is devoted to the reproduction of the species, and does not eat. In another allied form, the posterior half becomes self-divided into as many as six parts, each acquiring the cephalic appendages before dividing, and thus the Worm wanders about for a while, with a train of six mothers crammed with ova formed of its own tail. These separate, and die in giving birth to their ova.

The family of Leaf-bearing Worms, the Phyllodocidae, contains very beautiful Worms, which are easily distinguished from all the other Annelids. They are usually of a linear, elongated figure, and the body is furnished with a series of foliaceous lamellæ on each side, somewhat resembling elytra. They form a border, originating immediately above the insertions of the feet, and are in reality the cirri metamorphosed into leaf-like appendages. These structures are supposed to be useful for respiration; but, in addition to this, they are equally useful as organs of locomotion, for, as they follow the motions of the feet, and are capable of being partially altered from a horizontal to a perpendicular position, "they act as a bank of oars, and must be especially useful when the Worm glides from a solid surface, and finds itself unsupported in the water. Hence the species are quick and lively,



PHYLLODOCE KINBERGII.

and swim with considerable ease." The Phyllodocidae are provided with a very large proboscis, the under side of which is roughened with rows of fleshy papillæ. The one-branched feet, independent of their leaf-like appendages, are rather small, and the setæ, which spring from them, and of which there is only one brush, are slender and elegant in shape.

The genus *Myxostomum* contains little discoid parasites covered with vibratile cilia, and they have four pairs of suckers on the sides of the belly. They have a proboscis and five pairs of

* *Nephtys caeca*.

† *Syllis prolifera*.

feet, with two hooked setæ and cirri or pimples. There are no blood-vessels. These curious worms live on the surface of Comatulæ, kinds of Echinoderms. Their larvæ are ciliated all over, and the head and feet develop gradually. Probably the position of the worm is amongst the Polychætæ.

SUB-ORDER TUBICOLÆ.—THE TUBE-MAKERS.

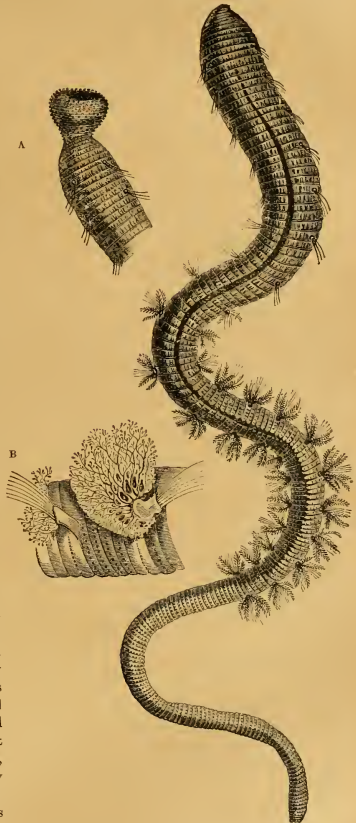
These worms live in more or less solid tubes, which they construct of different substances such as mud and excreted mucus mixed with calcareous matter, grains of sand and pieces of shells. Some live in mud, or in penetrations in rocks, and others drag their tubes after them. The Tubicolæ have a not very distinct head, a short, often not projectable proboscis, and no jaws. The branchiæ are either deficient, or are limited to two or three segments behind the head. The exception is in the Lob Worm, where they are placed on the back of the median segments. There are numerous filiform tentacles and tentacular cirri on the head, and one or more opercula on it. The feet are short; their accessory structures are small, and are of no use in swimming; but the dorsal lobes of the feet have capillary setæ, and the inferior are projections with hooked setæ or flat hooks. The eyes may or may not be present, and are found in many situations, as are also the branchial tufts, when they are very numerous. The body may be divided into two or three regions, the segments of each differing in their shape and in the kinds of appendages. They are not carnivorous, and are said to feed upon vegetable matter. The long tentacles are of use in building the tubes.

The development of these worms may be in some instances retrogressive; organs degrading and degenerating for want of use. In one group (*Spirorbis*) the eggs and larvæ are carried about by the mother in a pouch, and when they are able to construct a tube for themselves they escape. The larvæ are mostly free and ciliated, and they gradually lose the cilia, and assume the form of worms, and have feet and tentacles. Some roam about in this state, protected by their membranes, and finally grow eyes and auditory sacs, and begin to reproduce.

The Tubicolæ are divided into numerous families, and a great number of genera. The individuals are excessively numerous, and live at all depths on the sea and ocean-floor. Amongst the most interesting of the families is that* which contains the common Lug or Lob or Fishing Worms.†

* *Telothuside*.

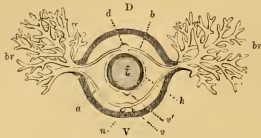
† *Arenicola piscatorum*.



LUG WORM.

A, anterior extremity of body, showing trunk; B, one of the body-rings, showing branchiæ.

In general form they are long, cylindrical, somewhat inflated anteriorly, and a certain number of the segments are provided with beautiful arbuscular branchiæ. In some of the species these branchiæ are finely tinted, and the worm itself is often of a carmine colour, or of a deeper red, though sometimes it is brownish, and at others of a blackish-green, according, in a great degree, to the nature of the ground in which they are found. The Lug Worm is a common species, and is well known to the fishermen. As Mr. Gosse says, "it is rather an uncouth-looking creature;" and the specimens he found were, in colour, like "what a tailor would call an invisible green." The body is composed of a considerable number of segments, and thirteen of them are furnished with branchial tufts. These branchiæ are arborescent in form, of a red or purple colour, and are said by Gosse, from an examination of the animal in life, to be protrusile, and to consist of a great number of short, incurved filaments, which have the power of independent motion, "moving with a sort of grasping action." The first six segments are provided with setæ only, and have no branchiæ.

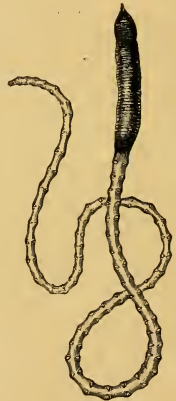


TRANSVERSE SECTION OF LUG WORM.
(After Gegenbaur.)

D, dorsal side; V, ventral side; g, ganglionic chain; i, intestinal canal; br, branchiæ; v, vascular abdominal trunk; a, b, branchial vessels; d, dorsal trunk; c, branch surrounding the digestive tube; v', ventral intestinal vessels.

The bristles are described by Gosse as pointing upwards and a little outwards, as very fine, and gradually tapering to a point, where they are clothed with the most delicate barbules. The Lug Worm attains the length sometimes of ten inches, and is found on various parts of the coast, in rather shallow water, preferring a station near low-water mark, and burrowing there in the sand, or—what perhaps they rather choose—in a somewhat muddy bottom. Their locality is easily detected, from the spiral rolls of sandy excrement, coiled like ropes above the aperture of the burrow, which is about two feet deep. In this hole the worm

lives, with its head downwards; and the process by which it excavates this dwelling is very curious and interesting—the worm swallowing the sand as it scoops it out with its anterior portion, and then lining the hole it makes with a glutinous fluid excreted from the skin. In some parts of the English coast the Lug Worm is very much esteemed by fishermen as an excellent bait. Dr. Johnston gives a most graphic description of the scene which occurs, in the neighbourhood of Berwick Bay, on the occasion of a party of "baiters" going to search for these, to them, valuable worms. "Almost at any season," says he, "when the tide has withdrawn itself within the limits of the ocean, the idler who has wandered down to the shore may, perchance, notice a group of men, girls, and boys hieing thither with a glee that he might almost envy. Some carry a small spade, round, and very sharp on the edge, and mounted with a long handle; and others have a little shallow bucket, held by a twisted cord fixed in a hole on each side of the brim. They are a picturesque and happy group. They go direct to a sandy bay, which reaches from the shore to the lowest ebb, and is made a little sinuous by the ledge of rocks on each side that define its limits. Over this bay our group disperse themselves, every one as his experience guides him, to the spot most favoured by the Lug Worm. Here, either directed by some peculiarity in the holes of the surface, or often, as I think, by mere guess, the bait-seeker plunges his spade deep into the sand—not by pressure of the foot as a gardener does, but by the force of the arm only; and then he throws out the sand, whence his attendant boy or girl picks out the writhing worm, and tosses it into his bucket, the bottom of which has been just covered with a little sea-water." The family Clymenidæ inhabit long sandy tubes, and have neither branchiæ nor tentacles, and *Arenia fragilis* may be taken as a type. The Opheliadæ have but few segments, no feelers, no eyes, and one set of branchiæ, limited to the middle of the back, one on every segment. There are stellate microscopic bodies in the perivisceral



ARENIA FRAGILIS.



EUNICE AND CIRRATULUS.

fluid. The Ammocharidæ have long segments, with a crown of ramified lobes in front, and their digestive apparatus is within the sanguiferous system; and the Aricidæ with a slightly depressed round body, made up of numerous short segments, have the head without tentacles and cirri, but the buccal ring carries dentigerous tubercles. They have short lanceolate or filiform branchiæ, and a short, very slightly contractile proboscis.

FAMILY CIRRATULIDÆ.

The genus *Cirratulus* is characterised by its sub-cylindrical vermiform body being composed of numerous narrow segments, and by its conical head being small, and generally deprived of tentacles. The feet are small, and form a double series along each side. The branchiæ are very peculiar, resemble cirri in their general appearance, and show themselves as long, filiform, tortuous filaments, springing from the back or margins of the segments. The form of the body of these worms is very like that of the Earth Worms (*Lumbrici*), to which they were referred by the earlier writers. One of the commonest species of *Cirratulus* on English shores is the Northern* *Cirratule*, found on several parts of the southern coasts, such as Devonshire and Cornwall. It varies from three to six inches in length, and individuals even nine inches long are occasionally found. The body is rather less than a goose-quill in calibre, of a brown or yellowish colour. The head is very small, the segments of the body very numerous, and the branchial filaments are found in greater abundance near the head than on the body. It lurks under stones, in a somewhat muddy soil, in which it forms burrows similar to those of the Earth Worm, and into which it retires slowly, when disturbed. The filaments by which it is so remarkably distinguished, and which curl around it like so many parasitical worms, are the branchiæ, or organs through the medium of which the blood is exposed to the influence of the air, and fitted for the purpose of life. So says Dr. Johnston; and in further describing these organs, he tells us that each consists of a large central vessel carrying red blood, surrounded by a white gelatinous transparent membrane, and that they are consequently of a fine red colour. The setæ of the feet are of two kinds. The upper, or superior bundle, is composed of about six—three long and slender, and three shorter, but comparatively stout—and all simple, unjointed, and acute. The inferior bundle has only three in the upper segments, diminishing to one only in the caudal extremity, and all stout and curved, according to Dr. Johnston, like the italic letter *f*. A more beautiful species than the one just mentioned is called the Tentacled *Cirratulus*, and is possessed of very numerous branchial filaments throughout the length of its body. It is four inches long, rather narrowed in the middle of the body, and consists of nearly 230 segments. The colours of this species are more brilliant than those of *Cirratulus borealis*. Another of the Cirratulidæ† is an inhabitant of the shells of *Cyprina islandica*, one of the hardest and most compact of British shells. It lives in a straight or slightly sinuous furrow drilled in the shell. The worm fits the furrow exactly, and when under water it gradually protrudes the tentacles and filaments from the circular aperture. The filaments are laid along the shell, and either kept quiet or in slight movement. It is about an inch long and scarcely a line in diameter, and how it makes the hole and channel in the shell is certainly a great puzzle. It lives on the British coasts.

The four-horned *Spio*,‡ with a long slender sixty-jointed tapering body, termi-



TROPHONIA PLUMOSA.

nating in two short styles, and with long cirri and two very long tentacles on the head, near four black eyes, is a member of the family Spionidæ. It is pale in colour, and has pink cirri, and makes a very slender tube composed of adventitious matter slightly agglutinated together, and placed usually on Sertularian Zoophytes. Amongst this family are some remarkable forms, which have not only internal ovaries, but also external ones like bunches of grapes in shape (genus *Lepidoceras*).

A small worm, from six to eight lines in length, worm-like in shape, with a small head and two

* *Cirratulus borealis*.† *Dodecaceria conchorum*.‡ *Spio quadricornis*.

great tentacles projecting from it, has on certain segments a branchial cirrus springing from the back, and as long as half the diameter of the body.*

The family Sternaspidæ have very short bodies, the anterior region thick and carrying three rows of setæ, and there is a corneous shield near the end beneath. On the other hand, the Pherusiæ have long cylindrical bodies with two strong forked tentacles on the head, and the buccal papillæ and branchial filaments are retractile. The first or second segments carry very long setæ, and in some the branchial organs are on a peduncle. *Trophonia plumosa* is one of them.

A great host of Tubicolæ live upon most shores, and have their tubes coated with broken shell, gravel, or sand, and membranous within and open at both ends. Some have their tubes visible and

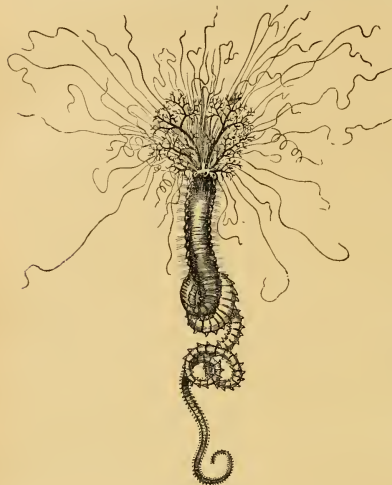
always covered with water, and others bury them in sand or mud, raising the orifice a little above the earth. These work between tide marks. Many live in groups, and are said to be gregarious, and their tubes are very fragile, being composed of sand.

All these tube-makers belong to a large family, the Terebellidæ. The animals are worm-shaped, thick in front and narrow behind. The cephalic region is not distinctly separated from the buccal ring, and often has a collar. There are numerous tentacles, filiform in shape, and divided into two groups around the mouth. There is no proboscis, and there are branched or comb-shaped branchiæ on some of the anterior segments. In some genera there is a transverse row of stiff golden bristles on the dorsal margin of the post-occipital segment. The segments are very numerous in some, and the worms attain the length of eight to nine inches, or more. The colouring is very pretty, and the shape of the setæ is lanceolate, hooked, siphon-shaped, and knobbed.

The larvæ of the Terebellidæ are covered with cilia, except at both ends,

where several bands of cilia become apparent; they have auditory sacs. This is the case in *Terebella conchilega*. When growth has proceeded so as to develop feet, the cephalic lobe becomes distinctly visible, and it has two eyes and one tentacle. At first there are only single setæ, but when the *Terebella* begins to construct its tube, forked setæ and branchiæ appear. Some of the larvæ crawl on the sea floor, and the others swim freely. The full-grown worms have the tubes made up of slimy matter which has entangled pieces of sand and stone; and one forms a case of loose sand large enough to permit it to turn within and to use either end for the projection of its tentacles. A Scottish species covers its body with a web made up of the finest threads, almost invisible from their slenderness and extreme transparency. The web extends far beyond the body, and puts one in mind of that of a Spider. Dalyell states that a specimen nine lines long, had a web covering an area fifteen lines square. The threads are fixed as high as the length of the worm, and below also, and are secured to neighbouring objects. The web serves to support the ova. Moreover, this weaving species constructs a semi-cylindrical shell of sand or mud, but it is not large enough to include the body and head perfectly, so it is abandoned very constantly for a new one.

* *Leucodora ciliata*.



TEREBELLA EMMALINA.

Finally, a common species has its case horizontal and adherent throughout, to its supporting shell or stone. It is generally found on old bivalve shells, is cylindrical, open at both ends, sinuous, and from six to ten inches long, thicker than a quill, and is coated with shell and gravel and pieces of *Sertularia*.

One of the *Tubicolæ*, which forms its tube of agglutinated grains of sand, has its home free, conical, and widely open at both ends. The ill-defined head has a row of prominent bristles in two fan-shaped sets above the mouth, which is overhung by a fringe of short channelled tentacles. The branchiæ are in two pairs, on the sides of the third and fourth segments. The thoracic portion of the body is greatly developed, and the segments form setigerous feet on each side, but the tail end is small and indistinctly segmented, and has no feet. *Pectinaria belgica*, which has a straight tube, lives on the sandy shores, within the lowest tide-mark. It varies from two to five inches in length, and stands immersed in the sand perpendicularly, and when active, searches all around the opening with its tentacles for grains of sand, shortening, lengthening, and twisting these organs in a most workmanlike manner, and applying the grains to the top of the rim of the tube. The animal can turn in its tube, which is as thin as paper, for only a single sand grain is placed one over the other, and the whole is lined with a slight silky coating within. It is the type of the family *Amphictionidæ*, whose genera are world-wide.

The last family to be noticed forms either calcareous or membranous tubes, and contains some of the most beautiful objects of the aquarium. The *Serpulidæ* have a vermiform body, with short segments usually well divided into two regions, the front, or thorax, and that behind, or the abdomen. The cephalic lobe is continuous with the next ring, which usually has a collar. The mouth is situated between spiral or semicircular branchial fans or laminae, more or less supported by a dense tissue. There are two or three tentacular cirri. The dorsal lobes of the feet carry fascicles of simple setæ in the front part, and the ventral lobes hooked setæ. In the hinder part, the hooks are on the upper lobes, but they are often absent, and the ordinary setæ also.

There are two sub-families, the *Sabellinæ* and the *Serpulinæ*.

Dr. Baird writes:—"A very handsome species, and one of the most common found on our coasts, is the 'Fan Sabella' (*Sabella penicillus*). The animal is from twelve to fifteen inches in length, and as thick as a common goose-quill. It is of a brownish-orange colour, and composed of numerous segments. There is no proper head, but the anterior extremity is furnished with branchiæ, which form a 'pair of remarkably elegant, large, fan-shaped tufts, of a straw-yellow colour, beautifully spotted and branded with brown, yellow, orange, green, and red, and about two inches in height; each tuft consists, in an ordinary specimen, of more than thirty (sometimes as many as eighty or ninety) filaments, densely fringed, and united together by a common cartilaginous membrane at the base.' The cilia of the fringe are simple, and the uncini, or hooked setæ, are arranged in such a way 'as to resemble the denticles of the tongue of a zoophagous mollusc.' The bristles which their feet bear 'are of a golden yellow, collected into a cylindrical fascicle; and as each bristle is thickened or kneed where the point begins, the apices of the whole are made to converge and form a conical termination.' The tube in which this worm lives is long, flexible, and cylindrical; smooth outside, the mud or fine sand of which it is constructed being cemented by a kind of glutinous secretion. In some of our creeks and tidal rivers these animals abound in immense numbers, and on the coast of Essex they are known to the fishermen by the name of 'Hassocks.' When dredging in the river Roach, I have often come upon banks where they existed in hundreds of thousands, and appear in masses of large extent, growing erect like a standing field of corn."

Sir J. Dalyell gives us a very interesting account of this fine species, under the name of *Amphitrite ventilabrum*. He describes it in great detail, and the formation of its tube is given with graphic accuracy. The little organs which he calls "trowels," and the "scoop," are extremely useful, as the following account clearly shows:—"To catch and collect the muddy material necessary for the work, the branchial fans are spread out into a semicircle, so that when the two are brought into contact a wide funnel is formed. Once in the funnel, the muddy matter is forced down the rachis of the filaments by the play of the ciliary fringes, and brought within reach of the singular organ at the base of the funnel by which the mud is selected and applied, just as a mason would lay lime on with

his scoop, and then mould and smoothen it with his trowel." These organs, described above, receive the pellets of mud which the animal mixes up "with an adhesive secretion, furnished probably by the collar of the cephalic segment, and by the organs just mentioned. It is thus rendered consistent and tenacious, and fit to be employed in raising the edge of the tube. To that position the material is raised by the tongue and trowels, aided by a general elevation of the head; and it is fashioned into shape by the same scoop and trowels, curved over the exterior circumference as far as they can be stretched, and smoothed and polished by their motions, while clasping it with their pressure; and thus the tube is built up." When clear and perfect, says Dalyell, this tube bears the narrowest resemblance to a tube of caoutchouc manufactured by human art.

The branchial plumes are the most striking part of the structure of this worm, and an enumeration of their parts may well fill us with wonder and admiration. "If the plume of an adult," says



ORTHONIA FABRICII.

Sir John Dalyell, "displays eighty branchiæ, with five hundred cilia on each side, here are no less than forty thousand organs endowed with voluntary, distinct, and independent action. So many other parts are alike privileged in their own peculiar motion without the participation of the rest, that it is no exaggeration to affirm that the will of this timid, lowly, defenceless creature is

fulfilled through the control of fifty thousand living parts." None of the Annelids, we are told by those who have studied the history of this interesting worm, is more richly endowed with the power of repairing wounds and losses.

One of the Sabellinae is remarkable for the fewness of its segments—the same number as in caterpillars—and the presence of eye-spots on the front and also on the tail segment. The species *Orthonia fabricii* has a body three or four lines in length, and is vermiform; it has a small fascicle of retractile bristles on each side of the segments, and the branchial tentacles are one-third of the length of the body, are straw-coloured, and rise from three stalks forming two dense tufts. The tube is cylindrical, and about twice the length of the body, and it is placed erect, on the roots of small seaweeds (*fuci*). It is made of fine mud, cemented by a glutinous secretion, and lined within by a skin. If the worm be removed and placed in clean water, it soon forms a new tube-skin; and when the worm has its tube formed, it is very lively, expanding its dense branchiæ in a wide circle.

The larvæ of this family have one zone of cilia, and have two eye-spots and two ciliated auricular appendages on the back, in front of the zone. Segments are preceded by setæ in the relative position, and the auricular appendages divide and form the four principal branchial rays, and their number augments by budding. Finally, the segments and setæ become developed.

The sub-family Serpulinae have a ciliated thoracic membrane, and the ventral and dorsal surfaces partly covered with cilia, and usually there is an operculum at the extremity of a tentacle. They make a calcareous tube. In the genus *Serpula*, the operculum which closes the tube-end is horny and rarely calcareous.

Serpula vermicularis, or *contortuplicata*, inhabits a round shelly tube, tapered regularly backwards, and marked on its dorsal surface with a more or less distinct keel. It is about three inches long, and its aperture is circular, with an even or somewhat everted rim. Many tubes are usually found growing together, adhering to some old shell, a bit of broken pottery, or a stone, all much intertwined, and mutually adherent. The worm itself is only about an inch in length, and there is a well-marked difference between the thorax and abdominal portion. The former carries on each side prominent tubercles in place of feet, which are vigorously portusile, and within which bundles of strong bristles are thrust to and fro. On the upper part, extending half across the back, is a row of microscopic hooks, wielded by long, thread-like tendons, which are fixed on mechanical



NERVOUS SYSTEM OF
SERPULA CONTORTU-
PLICATA.
(After Gegenbaur.)

a, upper, b, lower ganglia of pharynx; c, ventral trunk; d, nerves of mouth; and e, of antenna.

principles to the attached end of each hook. By the aid of these, the Serpulæ very cleverly withdraw themselves with lightning-like rapidity on alarm. "These organs are formed on the model of a hedger's bill-hook, only that the edge is cut into long teeth. Carefully counting them, I have found that each Serpula carries about 1,900 such hooks on its corselet, and that each of these being cut into seven teeth, there are between 13,000 and 14,000 teeth employed in catching the lining membrane of the tube, and in drawing the animal back." The branchiæ consist of most elegant comb-like filaments, richly coloured, arranged in two rows around the front extremity, one row on each side of the mouth. They are graduated in length, and are so affixed that, where the rows meet behind, they can be thrown in, so that a vertical view of the circular coronet shows a great sinus in it. These brilliant gill-tufts form the most attractive feature in these elegant worms, and are individually most exquisite examples of mechanical contrivance. Examined under a low microscopic power, they present a most charming spectacle. Each filament consists of a pellucid, cartilaginous stem, from one side of which springs a double series of secondary filaments, like the teeth of a comb. Within both stems and filaments the red blood may be seen with beautiful distinctness, driven along the artery and back by the veins (which are placed close side by side), in ceaseless course, contributing a very striking spectacle. The exterior of these organs is set with strong cilia, so arranged that the water-current is vigorously driven upwards along one side of the filament, and downwards along the other." This current brings the food destined for the nutrition of the animal into the funnel formed by the branchiæ, at the bottom of which is the mouth, along with a quantity of water, which, again, is expelled by means of a ciliated lining of the hinder parts in a strong current impinging against the closed end of the tube, and which carries with it all extraneous or fecal matters. (Gosse).



SERPULA VERMICULARIS.

Protula dysteri is a many-segmented form, and its delicate tube is white, calcareous, more or less wavy, and attached to a solid body by one end. Rising from a fixed base, these worms unite together side by side in irregular bundles, which leave spaces here and there between the tubes like a solid network. Each tube has a circular section, is thickened at intervals, and obscurely annulated. When active, the *Protulæ* issue from the tubes, and each spreads out its eight branchial filaments and displays its red cephalic end. Another species, with the tube about five or six inches long and about the thickness of a goose-quill, is very cautious, and will remain in its tube for hours without projecting its branchial tufts; but when they are slowly put forth, and then expanded, their beauty is extreme. On the slightest vibration of the water the worm retreats. This worm has no operculum, and the genus has a vast range, being found in the Mediterranean, the Atlantic, and West Indies. Huxley has shown that when the *Protula* attains a certain length, all the segments behind the sixteenth become separated as a new zooid, by the conversion of the seventeenth segment into a head and fore part, as in *Syllis prolifera*.

The dredgings in the North Atlantic yielded many small tubular shells, slightly curved and open at both ends. One end is wider than the other, and the whole may be from one to two inches in

length. They were the tubes of *Ditrupa subulata*, one of the Serpulines. This animal has two sets of branchiæ, rolled up spirally, and there are six fascicles of bristles on the body. The operculum is concentrically striated. These worms live at considerable depths, and the coral *Caryophyllia borealis* grows upon them. More Serpuline-looking, but very slender thread-like shining tubes in masses, are often found below low spring-tide mark in Devonshire, and they belong to the genus *Filograna*.

The genus *Spiroboris* is very familiar to folk that pick up the long seaweed on British coasts. On it there are small, flat, spiral, or twisted shells, with at least three turns. It is a tube formed of carbonate of lime, and is attached by one surface entirely. When living, this tube contains a little worm which projects its filamentary branchiæ at one end, and which has one or two trap-doors or opercula. The young undergo a kind of incubation within the tube, in a process or pouch, within the body of the parent.

THE SUB-CLASS HIRUDINEA.—THE LEECHES OR SUCTORIAL ANNELIDA.

Formerly, nearly everybody was familiar with the appearance of a Leech, for one or more were frequently ordered to be applied to tender and inflamed parts of the body by medical men. But now that blood-letting is not required to be done so frequently, the Leech is really very rarely seen. Some persons who sell Leeches keep them in darkness, and crowd a multitude together; but more reasonable people keep a few in a fresh-water aquarium with a secure top. There the Leeches may be seen, occasionally swimming with an undulatory up-and-down movement, and they then look flat, long, and rather pointed at both ends. When they come to rest at the bottom or fix on to the sides of the glass, their shape alters, and they become shorter, thicker, and more cylindrical, retaining, however, some flatness at the under part, and a narrowing fore and aft. But it will soon be observed that there is a flat disc on each narrow end, or head and tail, and that it can be applied to the substance on which the Leech is moving or resting, so as to fix the body as if it were a sucker. There are neither legs nor feelers, and the outside of the body is covered with rings, one behind the other, and from 95 to 100 in number. The colour of the Medicinal Leech is greenish-olive or very dark green, with six yellow-reddish or yellow bands along the back, and the belly is yellowish-green with black spots.

On taking one out of the water, it will diminish much in size, and will contract, become much harder, and swollen in the middle, and on permitting it to rest on the hand it will after a while begin to fix the front sucker to the skin, and then a sharpish prick or series of pricks is felt, and the Leech begins to elongate and to move its body in a slightly undulatory manner. After some minutes the body begins to swell, and the front sucker is well fixed, and the part immediately behind it is narrowed, the rest of the body being plump. After a time the Leech becomes many times its usual thickness, and it suddenly lets go its hold, falls off, and some blood comes from the spot on which the sucker had fixed, as well as from the mouth of the Leech, which is then seen to be at the bottom of the sucker. It has removed a certain quantity of blood from the hand, and the wound has been made by three jaws disposed in a triangle, and having their fine, curved edges toothed. The suckers act by their muscular fibres clasping the surface and expelling the air or water, and this brings the jaws in contact with the surface, and each is moved backwards and forwards, the teeth being downwards and the fixed point upwards. The result is three wounds, each radiating from a common point.

In their early life the Leeches fix on to the larvæ of insects in the water and suck them, and after more growth, fishes and frogs are attacked and have their blood sucked. The Leeches then frequently leave the water and wander in damp places, and if they have the opportunity, they creep on to the skin of warm-blooded animals and gorge themselves. Their sucking is followed by a prolonged fast, and indeed it is very wonderful how long some Leeches will live without food. Possibly from six months to two years are occupied in the process of digestion. Leeches grow very slowly, and some years elapse before they arrive at maturity, and they are not fit for medicinal purposes before the age of a year or eighteen months. There are, according to Cobbold, three species of leeches used in medicine, the Grey*, Green†, or Dragon‡ Leech. When it was the fashion to use Leeches in the olden time, the medical man himself had the compliment of being called a "Leech"—a term appropriate enough so far as healing is concerned, but singularly inappropriate in all other respects,

* *Hirudo medicinalis*.

† *Hirudo officinalis*.

‡ *Hirudo interrupta*.

for no profession is so self-denying or so generous as the medical. The employment of Leeches is diminishing year by year, and now they are hardly ever used in England. In Paris, between the years 1825 and 1830, three millions of Leeches were used, and it was calculated that thirty millions were employed in France and England every year. All the ponds and marshes where Leeches were bred, or were found in a state of nature, were nearly exhausted. Now the rate of mortality is less, and Leeches seek other prey.

The Leeches have ocelli in the form of black specks; they vary in number according to the genus, and are placed in pairs. There may be from one to five pairs, and they are very sensitive, and are disposed on the anterior part of the front sucker. The Leeches appear to dislike certain scents and greasy substances, and their skin is exceedingly sensitive to pungent substances, such as salt. Moreover, from their behaviour in rising and sinking in clean water at certain times, they would appear to feel alterations in barometric pressure.

With regard to their bodies, the numerous rings do not correspond to as many segments, there being from three to five to each somite or segment. The skin is smooth and rarely tuberculated, and it has two kinds of unicellular glands. One set secretes mucus generally, or only at the mouth or sucker, and the other produces a chitinous material which forms cocoons, in which the eggs are included. Three layers of muscular fibres exist—the circular, the radiating, and the longitudinal. The nervous system consists of a ventral cord, divided into ganglia at regular intervals, and there are twenty-three in the common Leech, and the anterior and posterior ganglia are the largest, and seven are fused in front, into one mass. Above the pharynx the branches of the front ventral ganglion unite to form a ring and an upper lobate pharyngeal ganglion. A single nerve lies beneath the intestine, and it has ganglion cells; and many nerve-twigs terminate in the centres of little depressions covered by clear cells—the cup-like organs which are situated on the head and hinder, but not hindmost rings of the skin. The mouth is in or below the anterior sucker in the sub-class as a whole, it leads to a muscular pharynx, and some genera have a protusible proboscis which has retractor muscles, but no teeth. The jaws are made up of calcified chitine. There are salivary glands in the gullet, and the oesophagus leads to a long stomach, which has nine side-pouches or cæca. These cæca open into the stomach, and vary in number with the genera; usually they are simple, but in *Clepsine* they are branched. The pylorus has a circular contracting muscle, and the short intestine passes backwards between the two hindmost cæca, and the anus is dorsal above the hinder sucker. The circulatory system contains a red fluid with colourless corpuscles, and it flows in a small body easily between the organs and the skin, which resembles a series of sinuses or narrow ways. These may form two lateral pulsating vessels. In the Leech this “pseudo-hæmal” system consists of a median dorsal vessel, a median ventral cavity, in which the ganglionic nerve-cord lies, and two longitudinal trunks which anastomose with one another, and give off a network of vessels to the muscular layers. The respiration is effected by the skin, and in the genera *Branchelion* and *Ozobranchus* there are some processes of the skin at the margin of the body, which may have to do with respiration. The excretory organs, are tubes with glandular walls symmetrically arranged along the ventral aspect; they are either closed internally or open within, by a ciliated funnel-shaped orifice, while the outer opening may be on a small wart or tubercle on the side of the body. These are called segmental organs.

One great Leech belonging to the genus *Macrobdella* from Valdivia is an internal parasite, and measures two feet five inches in length. In a genus which frequents shell-fish—for many species live in the sea—the skin is ciliated. In another there are tubercles, and one genus has bristles. All the Leeches lay eggs, and they may be deposited singly or in numbers, and in this case they may be covered with a viscous web or with a spongy envelope called the cocoon, as already mentioned. When the young are hatched, they keep within the cocoon, and in from twenty-one to thirty days burst forth, and either keep close to their envelope or their mother, for a short time afterwards. They do not undergo metamorphosis, and whilst in some the sexes are separate, they are united as a rule.



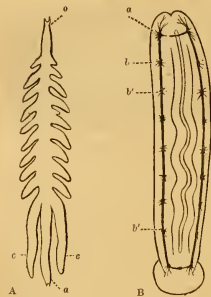
MEDICINAL LEECH.

Malacobdella grossa, belonging to the family Malacobdellidæ, is found between the mantle and the branchiæ of the Mollusc *Cyprina islandica*. It is nearly two inches long, and is flat, soft, ringless, and of an uniform flesh colour. The Histiobdellidæ have the posterior part of the body split, as it were, and the head has tentacle-like processes. There are two horny jaws in the pharynx, and the intestine is simple. *Histiobdella homari* lives upon the eggs of the Lobster, and it looks like the larva of a dipterous insect. The next family, the Acanthobdellidæ, have a flat fusiform body, pointed in front and armed on either side by well-hooked setæ. There is a posterior sucker, at the bottom of which is the anus.

The Branchiobdellidæ have the body almost cylindrical in shape when it is stretched out, and the segments are unequal. There are no eyes, and there are two flattened jaws, one over the other.

There is a sucker at the posterior end. The species live on the gills of Crabs and under the tail and at the base of the antennæ of the Lobster.

Some Leeches, which have a more or less protrusible proboscis, are termed the Rhynchobdellidæ, and they are divided into the Ichthyobdellidæ and the Clepsinidæ. The first group are the Fish Leeches, and the mouth is at the bottom of the anterior sucker. There are four eyes. Some species of *Piscicola* live on fresh-water fishes, others on marine fishes. The genus *Branchelion* has foliated-looking lateral appendages, and lives on the Electric Ray and on the Sole. In the Clepsinidæ, which are short, flat, gradually enlarged in front with three rings to each segment, and with an oval sucker slightly distinct from the rest of the body, there are from one to four pairs of eyes. The lower part of the body forms a kind of pouch for the eggs, the embryos of which escape and hang on to the mother. The proboscis is cylindrical, and the body is so transparent that the viscera can readily be seen; moreover, these Leeches move in a geometric manner by their suckers, or can contract their body into a ball shape like a Wood Louse. They carry the young attached to the belly for a considerable time after birth. *Clepsine bioculata* lives in places with but little water, lurking under stones and beneath the bark of decaying trees, and it feeds on the vegetable matter surrounding it, as well as on



A, INTESTINAL TUBE OF SANGUISUGA. B, NERVOUS SYSTEM OF MALACOBDELLA GROSSA. (After Gegenbaur.)

A, o, pharynx; c, posterior pole of intestinal caeca; a, anus. B, o, pharyngeal ganglion; b, first ganglion of the lateral nervous trunk, equivalent to the sub-oesophageal ganglion of other worms; b', the succeeding ganglia.

fish. Some were fed by Sir J. G. Dalyell on a vermilion-coloured larva of a dipterous fly. "When the prey was introduced to vessels containing the Leeches, they raised themselves on the sucker as if surveying around; then some one, bolder than the rest, advanced, and endeavoured to affix itself to the victim, which, being effected, the position was pertinaciously maintained in spite of its writhings and struggles."

The Skate-sucker* belongs to the genus *Pontobdella*, which has a leathery knobbed skin, and is about four inches long. It has no jaws, but it sticks fast and sucks out the juices of the fish in a most cruel and pertinacious manner. Its eggs are contained in capsules, and there is one young one to each capsule, which is attached to some substance or other in the sea. *Piscicola geometra*, the Great-tailed Leech, is found on perch and carp and fresh-water fishes, and it has large suckers, in comparison with its size. The genus *Hæmentaria* is used medicinally in Brazil; it has a two-lobed sucker.

The genus *Hirudo*, comprising the true Leeches, belongs to the sixth family, and its description has been given already. Associated with it in the same family are several genera, of which the following are remarkable. The term Horse Leech is used rather widely, and two genera have species so named.

Hæmopsis sanguisuga is called Horse Leech by the French, and it lives in lakes and ponds, being four inches long and half an inch broad. The long body widens backwards, and the large mouth has a protruding upper part. It has ten eyes, and is green and black on the back and yellowish-green on

* *Pontobdella muricata*.

the belly. The teeth are not well developed. It appears to be terrestrial in its habits sometimes. They are common in Egypt, and the soldiers of Napoleon suffered much from them in his campaign. They also attacked the horses and cattle. These must not be taken for true Leeches, some species of which, especially in the tropics and even to the north, lead a life amongst damp vegetation, and attack Europeans with great ardour. Such are the Leeches of the Himalayas, Ceylon, the Philippines, &c.

Another so-called Horse Leech belongs to the genus *Aulostomum*, but it does not appear to suck blood or to worry horses.

The glutton *Aulostome*, writes Dalyell, "is an active, bold, and clever animal, frequently crawling out of the water, and apparently always ready to quit the vessel. None of the tribe surpasses it in voracity. Few animal substances are rejected. All kinds of fish, dead or alive, seem acceptable. Penetrating the cavity of the larger fresh-water shells, this Horse Leech takes up a permanent dwelling there, until emptying them of their contents, should it be able." The same author notices that these Leeches are cannibals, and that they will swallow even dead Leeches of different kinds. It feeds on Earth Worms, Grubs, and Snails. It has a long intestine with only two caeca. The genus *Bdella* has an oval sucker and four pairs of eyes, and is African, and the species of *Nephelis* have thin bodies and no jaws. One of these is the Eight-eyed Leech of ponds and lakes, and is a very active animal. It moves with an undulating movement, does not quit the water, and often fixes itself by the terminal sucker, and waves the body to and fro. They are carnivorous, and yet do not prey like the carnivorous Leech. They attack almost every small animal that comes in their way, and swallow it, more or less whole, by placing the sucker over it and then dilating their gullet. Small Mollusca, Earth Worms, Planariae, and even their fellows, are readily devoured. They are small, being from one and a half to two inches long and two or three lines broad. They are usually brown in colour, and may be speckled with yellow dots. They deposit their eggs in capsules, each of which contains from six to twenty ova, embedded in a gelatinous mass.

CHAPTER II.

THE GEPHYREA, THE WHEEL ANIMALCULES, THE ROUND AND THREAD WORMS, THE FLAT WORMS.

GEPHYREA—Bolster-shaped Worms—Characters—ROTIFERA, THE WHEEL ANIMALCULES—Structure—Classification—The Philodinidae—The Brachionidae—Other Families—THE NEMATHELMINTHA, ROUND AND THREAD WORMS—Characters—The Thorn-headed Worm—THE THREAD WORMS—The Genus *Trichina*—The *Trichina spiralis*—Description—Reproduction—Their Effects—The Whip Worm—The Genus *Filaria*—The Guinea Worm—The Ascaris—The Lung Worm—The Genus *Mermis*—THE FLAT WORMS—The Tape Worms—Characters—Reproduction—The Beef Worm—THE TREMATODA—THE TURBELLARIA—Classification of *Vermes*.

CLASS GEPHYREA.

THERE are many kinds of Marine Worms which resemble at first sight the Holothuria, or Sea Cucumbers, belonging to the Echinodermata (see Fig. 17, p. 272). Their bodies are usually long, cylindrical, without "feet," and there is no distinct separation into segments. A little trouble distinguishes the group, for the Gephyrea have neither calcareous bodies in their skin nor ambulacral regions on the body. These bolster-shaped Marine Worms live at great depths, with their bodies in the sand or mud or under stones. Some exist in the shells of Mollusca, and others in the interstices between corals. Footless, without a series of lateral bristles and suckers, these worms have their locomotion singularly defective; but a great many species have a proboscis, which is more or less retractile, and which is terminated by the mouth, and it may be used as an organ of prehension, and, to a certain extent, of locomotion. It is said that some species * perforate limestone; others certainly penetrate soft clays, † and one group, which has a crown of tentacles formed by numerous branchial filaments, resides in tubes. ‡ The species of *Bonellia* lead a more or less wandering life. When one of these Gephyrea is placed in water, after a while it elongates and appears to be soft, and the trunk or proboscis is put forth,

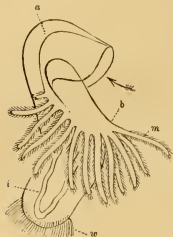
* Genus *Thalassema*.

† Genus *Phoronis*.

‡ Species of *Sipunculus*.

but on touching the animal it contracts immediately, becomes narrow, cylindrical, sharper at both ends, and hard. Both in the uncontracted and contracted condition, the body is swollen out here and there for a time and then contracted again. The Gephyrea have the sexes separate, and the young undergo metamorphoses. Most of them have a superior cerebral ganglion or a double one, an oesophageal nerve-collar, and a ventral ganglionic cord. This cord differs from that of the

class Annelida, for although it gives off nerves from its sides there are no separate ganglia at regular distances; but it is covered with a layer of cells which environ a canal, and it is placed within a blood-vessel. There are eye-spots directly over the brain ganglia, in some genera, and the proboscis is a tactile organ. The skin is analogous to that of the worms generally, but the transverse furrows do not amount to segmentation; numerous glandular follicles supplied by nerves are on the skin, and open out by pores in the epidermis. Bristles are rare, and there is chlorophyll in the skin of Bonellia. The muscular coats beneath are stout, and the outer is circular and the inner longitudinal, and the proboscis is retracted by bands of muscles from the body-wall. The proboscis is ciliated and also covered with bristles. In some the pharynx is armed with teeth, and there are salivary caeca opening into it. The intestinal canal is small in calibre, is within the perivisceral cavity, is long, and usually coiled. It is, as is the body cavity also, ciliated within. The vent may be dorsal, posterior, or even at the junction of the proboscis and body. When the vascular system exists, it consists of two long vessels, one along the median ventral line and the other dorsal, running



LARVA OF GEPHYREA.

(After Gegenbaur.)

a, cephalic lobe, upper lip; b, lower lip; c, vibratile crown; i, intestinal canal; m, muscular fibres.

along the intestine. In the genus Sipunculus these vessels are joined by one around the front of the body, within, and vessels are given off from it to the tentacles. The blood may be colourless, red, blue, or violet, and there may be a similar fluid in the perivisceral cavity containing amoeboid and flagellate corpuscles.

The genus Priapulus has a branchial tuft at its hinder end, and Echirurus has branched structures, receiving vessels from the ventral vascular trunk opening into the intestines. The tentacles of some act as respiratory organs. Finally, there are traces of excretory or segmental organs, in the form of four ciliated pouches on the lower part of the body, and they vary in number and use, being sometimes in relation to the process of reproduction. The males are not so numerous as the females, and differ in shape. In one genus (Bonellia) the male is like a Planarian in shape, and lives in the female. The eggs hatch and the embryos are free-swimming and unlike the parent. Their mouth is in the front part, and is overlapped behind by a double-lobed upper lip, which is round and ciliated, and on the ventral side there is a small ciliated lower lip or several ciliated processes. These become tentacles in some genera. Behind these lobes and mouth there is a curvulet of cilia, and then follows a long bag-like body with an intestine and anus. All this embryo or larva is not changed into the adult, but only a part grows into the mature form. Many of the larvae resemble the Rotifera in their circles of cilia, which surround the mouth, anus, and body.



SIPUNCULUS BERNHARDUS.

The Gephyrea are divided into three orders. The Gephyrea inermia have no bristles, and the mouth is at the extremity of a more or less retractile proboscis. Priapulus is the typical genus of the first family of this order. They are not uncommon in the Northern seas. The genus Sipunculus is the most important genus of its family, the Sipunculidae, which have a retractile proboscis, tentacular arms, and a twisted intestine. Phascolosoma is another genus.

The second order is that of the Gephyrea armata, which have bristles on the anterior part of the body, and posteriorly also. The genus Bonellia, already slightly noticed, belongs to it, and also the genus Echirurus, which has an undivided proboscis.

One genus (Phoronis) forms the third order of the Gephyrea tubicola. *Phoronis hippocrepia*

lives in a tube, and has a crown of tentacles on the dorsal surface, the mouth being in the midst of them, and the anus opening far in front on the dorsal aspect. The embryo has a two-ciliated body, and that behind the mouth is produced into several lobes, and fringes the free edge of a broad fold of the back, which arches over the mouth. This young form has been called *Actinotrocha*. As it grows, a part of the skin of the lower part grows inwards, like a pouch, and becomes connected with the middle of the intestine of the embryo. Then it grows out again and covers the intestine in the form of a loop with it, as a projection. This forms the foundation of the adult form, and the tentacles of the embryo or larvæ grow into those of the adult. It is like the larva of an Echinoderm.

CLASS ROTIFERA.—THE WHEEL ANIMALCULES.

Leeuwenhoek found in the rain water of a leaden gutter animals which were considered animalcules, about the size of a small grain of sand, and which produced currents in the water by means of slender organs or limbs. These they protruded at pleasure. They had bodies of the shape of a pear, with a short stalk, divided into two tails for fixing them on to objects. The microscope gradually increasing in its powers, observers were able to distinguish vibratile cilia upon a protruded disc-like structure, capping as it were the minute animal, and the optical illusion of a rotatory wheel

of hairs produced by the uninterrupted succession of the strokes given by the cilia of the disc, caused these beautiful and nearly transparent creatures to be called Wheel Animalcules, or Rotifera. The general surface of the body of the Rotifer is not ciliated throughout, and is made up of a layer of clear transparent chitinous tissue, which even becomes shell-like in some, and is ornamented. It is quite

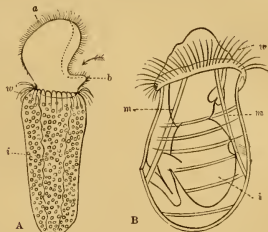
evident, under the microscope, that the body has cross markings and constrictions behind, amounting to imperfect segmentation. In front, or nearer the part out of which pass the discs with cilia—the trochal discs—the constriction is not usually seen, but transverse markings are often visible, so that the whole may be indefinitely marked with six segments. This outside coating may have spines or rigid bristles or hairs on it, and when there is a shell or carapace, this is secreted by the skin or by a special organ. The Rotifera have a digestive apparatus, and the mouth is a funnel-shaped cavity situated in the middle or on one side of the trochal disc; its walls are ciliated, and at the bottom of it is a muscular pharynx, or mastax provided with a peculiar armature or moving jaws. There are four pieces in the mastax, two side ones, the smaller, and two central, forming the incus. Muscles are attached to the movable mallei, and work them forwards and backwards, so that their ragged free ends work the food on the incus. A short œsophagus, also ciliated, leads to a digestive cavity lined with cells and dilated in front, giving off a large cæcum on either side. Behind, the digestive cavity narrows, becomes intestinal, and may open externally by a passage or vent. In some Rotifers the digestive cavity has no second opening, and is a sac without an intestine, and in the males of some forms there is no digestive track whatever, a solid cord of tissue existing there. The position of the



ROTIFER
VULGARIS.

mouth, close to the trochal disc, enables the cilia of this interesting structure to provide it with food by their lashing and current-making. The cilia of the digestive tract assist, and the morsel is crushed and smashed up, before entering the stomach, by the mastax.

A spacious cavity exists between the digestive organs and the inside of the skin and sides of the body of the Rotifer, and this is of course a perivisceral cavity. The outer opening or vent (cloaca) of the intestinal canal has a large thin-walled vesicle opening into it, which contracts and dilates regularly. This contractile vesicle has two delicate water-vessels, like narrow convoluted tubes which pass forwards giving off branches, and finally form a maze of tubes in the trochal disc. The branches are open at their ends, and as they are outside the digestive organs and inside the walls of the body



LARVA OF PHASCOLOSOMA (A) AND OF SIPHUNCULUS (B). (After Gegenbaur.)

a, cephalic lobe, upper lip; b, under lip; c, intestinal canal; m, vibratile crown; n, muscular fibres.

they must bring water from without into the perivisceral cavity, and in the main trunks cilia are seen moving with a flickering motion.

A large single nervous ganglion is placed on one side of the body near the trochal disc, and one or more eye-spots are placed upon it. Some Rotifers have a little sac filled with calcareous matter close to the ganglion, and it is probably a rudimentary organ of hearing. Moreover, a spur-like forceps armed with setæ is often found projecting near the ganglion, and it may be a nervous organ. The sexes are separate, and the ovarium and testis are simple glands which open into the cloaca already mentioned. The eggs are laid and left, or in some they are attached to and carried about by the female. In some Rotifera the eggs are of two kinds, and are termed summer and winter eggs, the last being enclosed in a shell.

In the sides of the body, beneath the skin and surrounding the perivisceral cavity, are muscular fibres in bands; some pass longitudinally and others encircle the body, many being of striped fibre. The jointed tail end is very telescopic in its movements in some Rotifera, and the terminating pincers hold on to objects by their muscles. But in some Rotifera the later stage of life is not passed as a freely-moving creature. Some form tubes to live in, and then their body ends in an adhesive disc. However, the young of these, especially of the genus *Laciniularia*, enjoy a free-swimming life, and have a circle of cilia around the large or mouth end of the body, and another circle around the tail end. This immature Rotifer is analogous to the larvæ of some of the worms already noticed, and as the adults have perivisceral cavities, a pharyngeal armature and water systems, and are more or less segmented, the necessity of classifying the Rotifera with the Vermes is evident. The trochal disc can be retracted and everted in some Rotifers, and as soon as it is well out the cilia begin to move, lashing forcibly in one direction, and producing by their general action whirlpools and currents in the water. They have to do with the providing of food, with removing impure and giving pure water to the water system, and also largely with locomotion, for when the foot is loosened, off starts the Rotifer, head first, and it guides itself here and there with the hinder part of its body. The trochal disc varies greatly in its construction, and forms a means of classification. Its margin may be continuous or divided, there may be lobes to it resembling more than one disc, and it may be provided with long tentacular processes. Finally, it may be used as a creeping organ, the Rotifer moving with its head and tail, over substances, like a Leech.

The Rotifera are found very universally in fresh, salt, and pure water, in pools, ponds, streams, and gutters. They even manage to exist in moist earth, and some make homes of the open cells of mosses and algae; some are parasitic within other animals. They are tenacious of life, and will revive on the application of moisture after they have dried up to a certain extent, but perfect desiccation is fatal. Their shape differs considerably in the different genera into which the class may be divided; some are sac-shaped, others are vermiform; one group lead a social life, being attached by their long tail ends to the number of forty or more. A fusiform shape is common, or that of an elongated cone. The manner in which the trochal disc is retracted within the body and again put forth is as remarkable as the similar process seen in some of the fixed Rotifers, whose delicate crown of long tentacles is unfolded and protruded with great grace and perfectness. The activity of these interesting microscopic animals is great under the stimulation of the sun and pure water containing minute animalculæ and vegetable organisms. They move and feed freely under such circumstances, directing themselves here and there, choosing the best spots for feeding, and fix themselves so as to work their disc cilia to advantage, or unfixing their forked tail, they move off by the same agency.

The classification of the Rotifera is not in a satisfactory state, and whilst Ehrenberg arranged them according to the peculiarities of their trochal discs, Dujardin classified them by their methods of locomotion. There are some very curious forms which have not all the characters of the Rotifera, and yet which have so many that they are allied to them, and this increases the difficulty. Thus in the parasitic genus *Albertia*, which lives in the intestines of Slugs and Earth Worms, and is $\frac{1}{8}$ th to $\frac{1}{4}$ th of an inch long, the body is cylindrical, vermiform, rounded in front, with an oblique orifice, around which there is a ciliated lip. There is a short conical tail, and the mastax is rudimentary, there being only one or two forceps-shaped pieces which seize the food.

A Rotifer of the genus *Lindia** also has a vermiform body, rounded in front; but it has no

* *Lindia torulosa*.

rotary organ, cilia, or eye, and it has a tail-like foot with two conical and short segments at the end. The mastax differs from that of the ordinary kinds, and is very complicated. The animal is about $\frac{3}{4}$ th of an inch in length. Another and smaller species (*Taphrocampa annulosa*) has a fusiform annulose body with a forked tail, and there is no rotary organ. Moreover, the genus *Balatro*, which lives upon the surface of Oligochaete Worms, has neither rotary organs nor eyes, and the tail is bilobed. Several genera, such as *Chetonotus*, *Ichthydium*, and *Dasydites*, have no mastax, nor eyes, nor trochal discs; but the body is furnished with bristle-like hairs, downy hairs, and cilia on the ventral surface; usually there are two tail-like processes. They are minute, and are from $\frac{3}{10}$ th to $\frac{1}{10}$ th of an inch in length, and would appear not to be Infusoria, but really Rotifera, allying the class to the Turbellarian Worms.

The first family of the Rotifera is that of the Philodinidae, and they are free-swimming forms, which can also creep like Leeches, the ends of the body being alternately fixed and loosened. They have two wheel-like rotary organs, and the body is somewhat spindle-shaped, and very contractile, so that it can be formed into a globose shape, and the powers of extension are considerable. The tail end or foot is jointed like the slides of a telescope. The genus *Rotifer* belongs to this family, and the common Wheel Animalcule is *Rotifer vulgaris*. It has a white fusiform body $\frac{1}{2}$ th to $\frac{1}{4}$ th of an inch long, gradually narrowed to the foot which has two horn-like toes. The anterior part of the body has a proboscis ciliated at the end, and the two eyes are placed there. The wheels are two in number, are round, and placed at the sides of the front part of the body.

Rotifer citrinus has a yellow body, and *Rotifer tardus* has the body deeply constricted into segments.

The genus *Philodina* has the two eyes on the region below the extreme end, and in general appearance the species greatly resemble *Rotifer*. Some are rose red in colour, and the ova when deposited are red. The ova are deposited in little heaps, and the parent remains in their neighbourhood, and even looks after the young.

A common species^a has two frontal red eyes, and at the tail end there are two horny processes and three terminal points or toes. They are large, being from $\frac{1}{8}$ th to $\frac{1}{10}$ th of an inch long, and are common. In the genus *Monolabis* there are no horn-like processes.

The other Philodinidae have no eyes, and in the genus *Callidina* the horn-like processes or the foot are present, there being six, and there is a proboscis. This proboscis, like that of most other Rotifers, appears to be an entry and exit for water, and it certainly is used in locomotion. One of the genus is parasitic on Crustacea, such as *Gammarus* and *Asellus*. One of the Rotifers found in Egypt has neither eyes, nor proboscis, nor horn-like processes on the foot, and the rotary organs are placed at the ends of processes on the front of the body. Another Egyptian form (*Typhlina viridis*) is simpler than the last mentioned, and has no processes for its rotary discs. Probably both of these Rotifers are young Philodinidae.

The second family, the Brachionidae, have a broad body more or less enclosed in a shell, or lorica. The foot is composed of short segments, and the rotary organ may be double or of three median and two lateral parts, these last only being rotary organs, the cilia of the others remaining extended without motion during the action of the other.

The lorica, or shell, is thick in this family, so much so as to prevent the internal organs being readily seen. The genus *Brachionus* has an eye on the neck, and the foot is forked. The mastax is very visible, and the crushing pieces are terminated by finger-looking ends made up of the same kind of hard skin or chitine that forms the lorica, which has projections on its fore and aft on either side.

The species are numerous, and the individuals also, and they are about $\frac{1}{10}$ th to $\frac{1}{15}$ th of an inch in length. One of the genera of the family differs from the last in having no forked foot, and the lorica is striated or has facets on it. Some of these Anuraea, however, have plain shells, but in most there are fixed or movable spines on its edges. Some of the family have two eyes, and one



MONOLABIS GRAECILIS.



BRACHIONUS AMPHICERUS.

^a *Actinurus neptunius*.

genus (*Pompholyx*) thus gifted has no foot, whilst the genus *Pterodina* has a disc on its foot, and is a very globose-looking form, and it carries its eggs for a time.

In the last genus to be noticed of this family (*Noteus*) there are no eyes, and the foot is forked, and the body has spines in front and behind, being usually large, or from $\frac{1}{10}$ th to $\frac{1}{7}$ th of an inch.

Amongst the Rotifera, with the trochal discs or rotary organs divided, are some in which the division is greater than in the two families just noticed. In the family Hydatina and that of Euchlanidotæ the wheels are many-parted, and the first have no lorica, whilst in the latter the shell is very well developed, and has curious appendages, such as setæ in the genera *Euchlanis* and *Stephanops*, hooks in *Colurus*, horns in *Salpinus*. There are spears or respiratory tubes in *Euchlanis*, and a helmet in *Stephanops*. In the genus *Monostyla* the foot is a sharp style, and in *Mastigocerca* the foot is as long as the body, or $\frac{1}{2}$ of an inch, and the lorica is prismatic. The genus *Squamella* has four eyes. The species of this genus carry their eggs attached to the outside of the body.



JAWS OF *BRACHIONUS BREVISIMUS*.
(After Ehrenberg.)

In many of the family the muscular fibres by which the shape of the body is changed are very visible. The nutritive organs are very obvious, and the intestine is simple and conical, with or without the part which represents a stomach. The water system, with its tremulous flapping of minute cilia within the tubes, is visible, and in most the nervous system is to be seen. There are no crushers or mastax in the genus *Enteroplea*; it has no eyes, and it is thus a very simple Rotifer, and segmentation in any degree barely exists, the small foot being forked. In Hydatina, another genus, there are no eyes, two jaws, and they are divided to show numerous teeth. *Hydatina senta* was the Rotifer which Ehrenberg especially studied, and it is common and very transparent. Its species are not very small, or $\frac{1}{200}$ th of an inch long.

Of the family Hydatinea, in which there is not an investing lorica, and the rotary organ is multiple, there are no less than eighteen genera, and they are characterised by the absence or number of eyes, the position of these organs, the nature of the foot and appendages to the body. There are several distinct rows or circles of cilia, which are distinctly separated from each other, forming the multiple wheel or rotary organs. Except in the genus *Polyarthra*, which has no foot, all the other genera have a long pincer-like process resembling a tail, and this genus is characterised by a single eye on the neck, and by the presence of six cirri or fin-like processes on each side of the body.

The species of the genus *Notommata* are sometimes parasitic, and undergo some degradation of form, and *Notommata tardigrada* has the rotary organ greatly diminished. Two species live within the beautiful microscopic alga, called *Folvox globator*, and another in the vesicles of a *Vaucheria*. The well-formed species have a single eye and a forked tail.

Notommata longisetæ has two setæ in the position of the tail, and several times longer than the body.

The *Triarthra* have two eyes, and *Triarthra longisetæ* has a tail, or foot, three times as long as the body, and very long cirri also. It moves in a jerking manner, and is $\frac{1}{200}$ th of an inch in length. It carries its ova attached to its sides, and may exist in such multitudes as to colour the water a milky white. Gosse has described *Asplanchna brightwelli* and *A. priodonta*. The females have jaws with a single tooth and a single eye-spot, and they are without feet and the end of the intestine. The males have neither jaws, pharynx, nor stomach.

The family Flosculariæ contains some very beautiful forms of Rotifers, but they are very aberrant from the group as a whole. The body is elongate, and the tail or foot is long, more or less imperfectly segmented and fixed. They are for the most part protected by a tube made up of a gelatinous excretion of the body, and extraneous substances or pellets of their excrement. The rotary organ is much modified, and is partly encased in some and is lobed in others, whilst in



POLYARTHRA PLATYPTER.

many it consists of a host of delicate filaments placed on a disc, which has, however, a circle of cilia on its under edge; or some fine tentacles may arise in a ring and be ciliated. Under all these conditions the cilia and appendages can be withdrawn into the body by the longitudinal muscular fibres, and also gradually everted. Moreover, the animal itself withdraws down its tube if disturbed, and comes forth again to a certain extent. There are usually, but not invariably, a stomach and mastax, and in nearly all there are eyes. In one set of genera the rotary organ is flexuous and extended, and has only one deep cut in it; and in the genus *Megalotrocha* the alimentary canal is singularly developed, and there are two eyes. In another group the rotary organ is entire, the genus *Ptygura* being the type.

The genus *Floscularia* has the lobes of the rotary disc three to six in number, has a tentacle-like proboscis at the side, and the cilia on the rotary organ are of two kinds, some very long and excessively slender and comparatively motionless, and others very small and not readily seen at the base of the long ones on the inner side of the lobes. The number of lobes varies, and five or six are commonest; they are thickened at the free margin. All the species make tubes of a delicate gelatinous secretion, and live on the surface of the leaves and twigs of water-plants. *Meliceria ringens* is a beautiful species of its genus, and is frequently found on water-plants, especially on *Potamogeton crispus*. The rotary organs are four-lobed, and the bodies are each in a tubular cavity.

The young are very interesting on account of their having a circular pre-oral disc, and two eye-spots, besides a second circle of cilia behind the mouth. Their shape, and this distribution of rings of cilia, cause them to resemble the larvæ of Annelida, and ally the class Rotifera very definitely with the Vermes. The genus *Laciniaria* has a bilobed rotary organ deeply incised ventrally, and there is a double crown of cilia. The individuals of a well-known species (*Laciniaria socialis*) unite, and remain fixed in the midst of a gelatinous environment.

Limnias ceratophylli, a form resembling the last somewhat, has only two lobes to its rotary organ, but its shell gets dark with age, from its collecting foreign bodies on it. It is a very typical form.

The genus *Stephanoceros* has five tentacles, instead of lobes of the rotary organ, and they are ciliated. It uses them to clasp its prey, and the body is attached by the base to a transparent carapace. The length of *Stephanoceros eichhornii* is $\frac{1}{8}$ th of an inch.

The genus *Ecistes* probably comes into this family, and one species which has been studied by Mr. Hudson makes pellets of its feces, and piles them up gradually as a wall to its gelatinous tube.

In considering the classificatory position of the Rotifera, the segmented condition of the body, the presence of a water system and perivisceral cavity must be remembered. The nature of the mastax and the rudimentary organs of special sense, the method of locomotion of some, and the tube-making of others should not be forgotten. And when these very characteristic peculiarities of the Vermes are considered, with the fact of the resemblance of some immature free-swimming Rotifers to the ciliated larvæ of some Vermes, the propriety of placing the class in that great group must be admitted. The Rotifera are not Infusoria, for their ova undergo a development not noticed in that group. Some minute worm-like animals, with a rounded head and ten or eleven segments, the last of which is forked, which belong to the genus *Echinoderes* (*Dujardin*), seem to link some of the Rotifera to the lower Crustacea. They are marine, have no limbs, but the body segments have paired setæ, and the head has recurved hooks. The nervous system is a single ganglion, and has eye-spots on it. Moreover, a Rotifer of the genus *Pedalion* (*Hudson*) has jointed setose appendages.



FLOSCULARIA TRIFOLIUM.

CLASS NEMATHELMINTHA.—THE ROUND AND THREAD WORMS.

A host of worms, mostly parasitic within man and the lower animals, and a few leading a free life, belong to this class. All have cylindrical unjointed bodies, which are, however, marked with rings,

or they are filiform, and narrowed at each end, and furnished with papillæ, or stylets, on the anterior extremity. The sexes are separate. The class is divided into two orders, the Acanthocephala and the Nematoidea, and in both there are no rudimentary organs of locomotion, such as false feet, and it is only in rare instances that setæ capable of moving are found. Usually the skin is thick and the muscular system within it is highly developed, so that these worms wriggle, twist, and move in a serpentine manner with great vivacity and persistence. Within the muscular layer is the visceral cavity which contains the blood and the digestive and reproductive organs. There are no special organs of circulation and respiration, but there is a nervous system, and there is a tactile power in the front of the body, especially when there are papillæ developed there. Simple eye-spots and eyes have only been noticed in the non-parasitic kinds. Great diversity exists in the shape of the digestive organs, and in one order they are absolutely deficient. The excretory organs exist, and are various in their shape and distribution. In almost every instance the sexes are in different individuals, and the egg may produce a worm like the parent, or a form which has to undergo metamorphosis of very strange kinds, one part of the transformation taking place inside one animal, and the other in a second and different kind of unwilling animal host. The parasitism of most is constant, but in some a host is frequented at one time only, of the life of the parasite. The parasitism is of a nature deserving the name, and the worms live in their unwilling host, and exist by absorbing his juices.

The Acanthocephala, or Thorn-headed Worms, have a genus whose name is explanatory of the principal peculiarity of the order.* They have a projecting trunk or proboscis which is armed with

hooks; the body is ovoid and oblong or cylindrical, and has neither mouth nor digestive organs. The trunk is used to fix the worm, or to enable it to penetrate the coats of the intestine of its host. The nervous system is composed of a ganglion with large cells, which give forth a nerve to the proboscis and another to the body; but there are no sense nerves. The species of Echinorhynchus are frequently parasitic within Invertebrata in their first stage of metamorphosis, and within Vertebrata in their second, and become perfect there. Thus eggs containing embryos are excluded, and these escape in the form of little elongate bodies armed in front with temporary hooks. They live in the water free, and are swallowed by, or penetrate from without, through the tissues into the digestive organs of small Amphipod Crustacea. After a while they cling to the tissues of the stomach and intestine of the Crustacea, and penetrate them, getting into the cavity beyond. There they loose their hooks and undergo a metamorphosis, becoming round or elongate things which might be called nymphs. If the

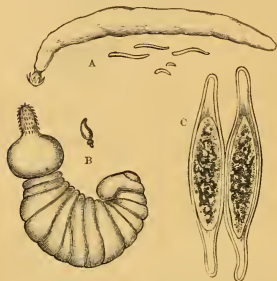
Crustacean should happen to be swallowed by a bird or fish, the Echinorhynchus is not killed, but it escapes from the prey and fixes on to the mucous membrane of the digestive organs of the swallower, and then attains its perfect form, living by taking in, through its skin, the nourishing juices of the food of its host. This process of development may be considered one of alternation of generation. Examples are very common. Thus one kind of Echinorhynchus affects the Water Flea (*Gammarus pulex*), and this is swallowed by the fresh-water fish, and another kind gets into the food of water-fowl, and becomes parasitic within it.

ORDER NEMATOIDEA.†

The Thread Worm group are round worms, with a long, fusiform, or filiform body. They are mostly parasitic, and usually have a mouth, a swollen gullet, and a straight digestive canal. The cylindrical body, generally very long for the width, has papillæ on the front of the body around the mouth, and sometimes sharp pricks and hooks, or a style in the interior of the buccal cavity. There is often a very muscular, dilated pharynx, and there may be a granular substance in the spaces left

* Echinorhynchus.

† Greek, *nema*, a thread.



A, ECHINORHYNCHUS ANGUSTA (nat. size and enlarged);
B, ECHINORHYNCHUS NODULATA (nat. size and enlarged); C, EGGS OF DO. (enlarged). [After Busk.]

by the muscular fibres or glands. The chitinous tube of the pharynx may have longitudinal projections called teeth, but the office of the gullet is that of a sucker or tube. In some Nematodea the intestinal canal, in part or wholly, undergoes retrogressive development during the parasitism. The skin, more or less tough, and often striated across, is formed of several layers partly composed of fibres, and rests on a soft, finely granular tissue with nuclei. Beneath this is a musculo-cutaneous envelope with flat and fusiform muscular fibres. The surface of the skin may be covered with ridges, tubercles, spines, or hair, and moulting takes place in the young. Some Nematodea have eye-spots, at the end of the body, with or without refracting bodies in them. Most have the sexes separate, and usually the males are smaller than the females.

Of late years much attention has been paid to a very remarkable Nematoid parasite which has been called *Trichina spiralis* by Owen. Gritty particles were found in human muscles, by the late Mr. Hilton, F.R.S., of Guy's Hospital, who recognised them as the results of parasites. Sir James Paget, when a student, first determined the existence of the minute worms which produce the gritty parts; and Robert Brown, the botanist, assisted, by lending his microscope to the now distinguished surgeon. In the year following, Professor Owen described the worm scientifically, from specimens sent him by Mr. Wormald, Paget's colleague. Leuckart discovered the history of the parasite, tracing it to its source and method of propagation; and Zenker explained the symptoms of infected men, and detected the young in the act of migration.

The worm was named from its very commonly being seen in a capsule, rolled up in a spiral shape. When mature and able to reproduce its kind, and therefore fully developed, *Trichina spiralis* is minute, and the male is about $\frac{1}{15}$ th, and the female $\frac{1}{10}$ th of an inch in length. The body is rounded and filiform, usually slightly bent upon itself, and is rather thicker behind than in front. The head is narrow, finely pointed, unarmed, and has a simple central, minute, oral opening. The tail of the male has a bilobed end surrounding the vent. The female is stouter than the male, bluntly rounded posteriorly, and the reproductive outlet is placed far forwards. The eggs measure $\frac{1}{1270}$ th of an inch from end to end. As observed in the muscles of the human body, the Trichinæ are young, not mature, and are spirally coiled worms in the interior of small oval cysts, which are scarcely visible to the naked eye. They measure $\frac{1}{75}$ th of an inch in length, and $\frac{1}{125}$ th of an inch in breadth, and often are gritty from the presence of salts of lime. Sometimes they are not thus encysted, and they measure $\frac{1}{30}$ th of an inch in length, and $\frac{1}{300}$ th of an inch in breadth. The history of the life cycle of the worm is as follows:—

The mature and reproductive Trichina inhabits the intestinal canal of Mammalia, including man, and its life lasts from four to five weeks, and they attain their full development and ability to reproduce on the second day of their introduction to their locality. The eggs of the female are hatched, as it were, within her uterus, and produce minute hair-shaped embryos there, and there may be from ten to fifteen thousand of them. The embryos are expelled from the body of the mother whilst in the intestines of the victims, and they soon drill their way through the mucous and muscular tissues of the parts, and then, traversing even serous membranes, get into the muscles. There they assume the form known as *Trichina spiralis*. The importance of the discovery of this series of changes is great, for it is clear that if the Trichinæ can be kept out of the digestive organs of an



INTESTINAL CANAL OF A NEMATOID. (After Gegenbaur.)



TRICHINA SPIRALIS.

B, worm; a, head; A, worm coiled up in capsule or cyst in muscle.

animal, it cannot suffer from the painful and dangerous disease which is set up by the young worms, as they grow to a certain life-stage, in the muscles. And, moreover, the only manner in which the Trichinæ can get into the digestive system is by their being swallowed alive, with pieces of improperly cooked muscle in which they are encysted. Men are infected by eating badly-cooked pork, the pig happening to suffer from the presence of the worm in its muscles. Leuckart stated that, as a rule, "swine obtain their Trichinæ from rats, to which latter we also, as natural bearers, have to convey them." Cobbold has shown the stupendous number of Trichinæ an animal may have within its muscles at one time, and he proved that 80,000 were in an ounce of pig's flesh belonging to an animal part of which had been unfortunately eaten, and had produced an epidemic.

The "Whip Worm"* has a long filiform neck two-thirds of the length of the whole body, and the surface of the skin has, on one side, a longitudinal band of minute wart-like papillæ. The Whip Worms infest the cæcum and the upper part of the great intestine or colon, and many thousands have been found in the human subject.

Cobbold describes the wonderful story of the life of one of the species† of the genus *Filaria*, and notices that the body of it is like a hair, uniform in thickness, and that the head has a simple circular mouth without papillæ. The neck is narrow and about one-third of the width of the body, and the tail of the female is single, bluntly pointed. They are three inches and a half long and $\frac{3}{10}$ th of an inch broad. The eggs are about $\frac{1}{10000}$ th of an inch in length, and the embryos derived from them are $\frac{1}{200}$ th to $\frac{1}{125}$ th of an inch in length.

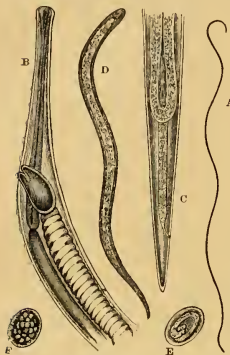
The embryos were first discovered in human urine, and Cobbold got eggs and embryos from a man from Natal whilst searching for the parasite called Bilharzia. In 1872 Dr. Lewis found these microscopic worms in the human blood, described them, and gave the species the name of *Filaria sanguinis homini*. In 1876 Dr. Bancroft found the eggs in the blood, and discovered, subsequently, the mature form already noticed, and observed that immense numbers of minute living ones are passed from its body.

Dr. Manson, in 1878, found the immature or embryonic *Filaria* in the stomach of Mosquitoes which had sucked the blood of man, and probably also that of birds. The female Mosquitoes, after gorging themselves with blood, repair to stagnant water to deposit their eggs, and during the four or five days thus occupied the *Filariæ* within undergo remarkable changes. Subsequently they become more fully developed, and escape from the Mosquitoes into the water, and may be drunk by man.

The largest known Nematoid Worm is called *Eustrongylus gigas*, the male measuring a foot and the female more than three feet in length. The breadth of this huge worm is half an inch at the thickest part. This worm is known to occur in a great variety of animals.

The Guinea Worm‡ is a Nematoid measuring from one to six feet in length, and having the thickness of one-tenth of an inch. The body is cylindrical, and has a pointed tail and a convex head, with a central mouth surrounded with papillæ. The body of the female encloses a prodigious number of hatched embryos when she is mature, and they may have the opportunity of escaping from their human host from the sores produced by the adult. The embryos escape into water and become parasitic in the small crustacea of the genus *Cyclops*, and undergo a change of skin and subsequent growth. This condition of larval development lasts about five weeks, and when the larvæ become perfect they may be accidentally drunk with the *Cyclops* by men and animals.

The Thread Worm,§ which is so frequently a parasite of children, also affects old people. The male worm, according to Cobbold, measures one-sixth of an inch, and the female from one-third to one-



FILARIA BANCROFTII. (After Cobbold.)

A, female (nat. size); B, head and neck; C, tail; D, free embryo; E, egg with embryo; F, egg with nutberry cleavage of yolk.

* *Trichocephalus dispar*.

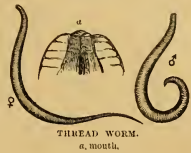
‡ *Dracunculus medinensis.* (Cobbold.)

† *Filaria bancroftii*.

§ *Oxyuris vermicularis*.

half of an inch in length, and the latter has a long hair-like tail with a three-pointed end, the tail of the male being blunt. The body is fusiform, and the front end is narrowed at the truncated head, which is sometimes rendered very conspicuous by a bulging of the transparent membrane which surrounds the mouth. This has three papillæ around it, and leads to a triangular œsophagus. There is no doubt that the worm is introduced in the form of an egg. The worms live in the cæcum, which is their proper position. They stray to the lower bowel and produce irritation there.

Several species of *Ascaris* are parasitic within children and adults, and affect monkeys, horses, dogs, pigs, bears, oxen, mice, birds, and marsupials. The species infecting man and the pig are sometimes identical, and this is the case in the example which must be taken as the type. The large round worm, which measures from four to six inches in length in the male, and from ten to fourteen in the female, is at first sight not unlike a pale Earth Worm. They are narrowed at each end, and the body is elastic and marked by numerous fine cross striations. This *Ascaris lumbricoides* is usually found solitary or in small numbers in the upper and middle part of the small intestine; from 100 to a 1,000 have been found. They wander into the stomach and are cast forth, or they may get up into the nostrils and escape. They may make their way through the coils of the intestine into the cavity of the body, producing inflammation and abscess.



THREAD WORM.
a, mouth.

The Lung Worm* is often fatal to calves, and a closely allied species attacks lambs. The eggs and embryos of the Lung Worm are found within the common Earth Worm, which swallows them mechanically, with its food of soil. Cobbold placed some of these embryos, or larvæ, as he calls them, which he got from an Earth Worm, on to the fronds of watered ferns, and he noticed them increase in size and organisation. Doubtless the parasites escape in due time from worms, and are devoured by their next hosts with their vegetable food. They do not go into the stomach, but pass into the bronchial tubes and set up much and often fatal irritation. A Strongyle† affects the stomach, however,



STRONGYLUS PERGRACILIS. (After Cobbold.)

A, head and neck; B, C, D, E, F, tail of female; G, section to show termination of oviducts; H, eggs.

and they are found in the fourth stomach and duodenum of Australian sheep especially. The Palisade Worm of the horse is a Strongyle,‡ and is remarkable for the severe injuries it does its host in its passage through the tissues. According to Leuckart, they pass into the body of an intermediate bearer before entering the stomach of the horse. From the alimentary canal they pass through the tissues and enter the blood-vessels, causing aneurism, and thence they seek to regain the intestinal canal, where they arrive at sexual maturity. It is during their migratory efforts that they give rise to dangerous symptoms, not unfrequently causing the death of yearling foals.

One of the Nematoids allied to the Strongyles§ has the male with a tail, surrounded by a ring or crown of fine, lancet-shaped flaps connected together by a delicate web. Probably these worms have something to do with hog cholera, a disease of the pork-producing districts of the United States. The gapes of fowls and other birds are produced by worms in the trachea or main air tube|| and the disease may be cured by careful operations.

The so-called grouse disease depends on more than one worm parasite, one of which is a Strongyle.¶

* *Strongylus micrurus*.

§ *Stephanurus dentatus*.

† *Strongylus contortus*.

|| *Sclerostoma syngamus*.

‡ *Strongylus armatus*.

¶ *Strongylus pergracilis*.

The genus *Mermis* has species which are parasitic within Insecta, and at a certain time they make their way out, by perforating their hosts, and hide themselves in the soil. They there reproduce, and the embryos are born viviparously and pass some time in the ground. They wander in search of an insect host, the caterpillar of a Tinea, or Moth, for instance, which they penetrate by means of a sharp stylet, that is hidden within the head when not used. *Mermis nigrescens* emigrates *en masse* out of insects, during hot weather, and being found on the ground in great numbers, gives rise to the popular belief that "it rains worms." After this emigration, the embryos live in the pharynx of a Planaria. The Humble Bee (*Bombus terrestris*), and others of the genus, are the unwilling hosts of a curious worm, one-fifteenth of an inch thick and an inch long, white in colour, blunt at either extremity, and covered with knobs, about 800 in number. This worm is the female of a species of *Sphærulearia*, and the male is 28,000 times smaller than the female, and is permanently attached to her. Another family of these Nematodea contains the genus *Gordius*, the embryos of which have a mouth, and are found within the bodies of carnivorous water insects. They penetrate outwards and get into the water and become sexually mature. The embryos coming from their eggs penetrate the larvæ of water insects, such as those of Tipulidæ and Ephemeridæ, where they become encysted. Then the carnivorous water larvæ and beetles swallow the others, and of course take in the parasites which rupture their cysts and live free in the visceral cavities of their bearers.

The Anguillulidæ are mostly non-parasitic Nematoid Worms, and some of them are known as paste and vinegar eels. Others live in the mucous secretions of animals, and some are dwellers in mushrooms. One gives rise to a diseased condition of the wheat ear. The young are hatched from eggs laid by the parent in the ear, and they become encysted. When the wheat dies down, the larvæ are set free and wander on the moist earth until they meet with some young wheat plants, up which they creep and lodge themselves in the developing ears. Here they become sexually mature, and nourish themselves at the expense of the inflorescence.

ORDER CHÆTOGNATHA.

Allied to the last-mentioned family of the Nematodea are the species of the genus *Sagitta*, which are associated in this order. They are long transparent worms with a special mouth armature and pectinate fin-like feet, placed horizontally at the sides of the body, and their rays united by a web. The head is distinct, and has two sets of hooks which simulate jaws on each side of the mouth. They swim freely in the sea, and live on small Crustacea.

CLASS PLATHELMINTHA.—THE FLAT WORMS.

These are the most lowly organised Vermes. Many are parasitic within animals, and some live in mud or in water, hiding under stones.

They are divided into three orders, of which the first is that of the CESTOIDEA,* or Tape or Ribbon Worms.

The Tape Worms, which are parasitic within many vertebrate animals, including man, live in the intestinal canals of their hosts, and are readily recognised by their long, flat, many-jointed bodies, narrow and small heads usually armed with hooks and suckers suited for clinging on, and gradually narrowing tail end. Some genera have species of enormous length, which consist of hundreds of joints or metameræ behind the head, and others have the head and a linder part not jointed and of no great length. None have any digestive organs, the nutritious juices of the host passing into the worms through their delicate integuments; and no special organs of sense exist. In the Tape Worms, both long and short, the head or scolex divides during growth behind more or less into a joint or metamere, which is called a proglottis, and in this last the reproductive organs are developed, there being none in the head itself. As growth proceeds, the successive joints are given off from the back part of the head, so that a long chain of them is produced, the oldest metamere being that at the tip of the tail. All these metameræ can produce ova. After a while, the time depending upon the maturity of the egg-producing apparatus, some of the metameræ break off and are set free from the rest of the worm, which still grows on as before. The growth of the metameræ from the back part of the head is thus a kind of budding, and as each metamere, when detached from the

* Greek, *kestos*, a girdle.

worm, continues to live until the ova are expelled, it is an intermediate state. The scolex or head is a kind of nurse; it is asexual and buds metameres, which are reproductive. The eggs produced within each of the metameres are numerous and too large to escape, except by rupturing the tissues; they may escape from the host, included in the metamere when this becomes separated, and the escape may be with the evacuations of the animal, or the metamere may move out by its own activity. Under both circumstances the metamere has a power of independent movement, and creeps slowly from the dung on to all kinds of moist substances, such as stalks of grass, leaves, and vegetables. In this case they are eaten, with the vegetable matters, by vertebrates. Sometimes the metamere falls into water, where it bursts, and the eggs are cast forth and are drunk by animals. Arrived in the stomach of their new host, the metameres are more or less digested, and the eggs are diffused there, or sometimes imperfect digestion may occur, and the brood may reach the small intestine. In some instances the eggs may be set free in the host by rupturing the metameres, and if they are then expelled there is a chance of their being eaten or drunken and getting into the stomach and intestine of a second host. The so-called eggs have tough shells, and the embryos within are totally unlike their parents. They are globular naked vesicles, the largest being 0.05 of a millimetre in length; they have a cuticle, and either six, or four, microscopic hooklets on their anterior extremity, with which they will, if they have the opportunity, bore inwards into the tissues of their future host.

These embryos are capable of motion, and under the influence of warmth and nourishing juices around them begin to migrate. Each brings the central pair of hooklets together like a wedge, and thrusts and twists them into the mucous membrane of its host. The other hooks move backwards, and finally the parasite reaches a small vein belonging to the portal system. By the flow of blood it is carried into the liver and can go no farther. Or it may get into other blood-vessels and be carried into the general circulation, and be deposited at last in some organ, such as the brain or in the skin. The little vesicle with its hooks may grow in the blood-vessel, which may form a cyst around it, or the parasite may penetrate the vessel and get into the tissues of the body, and a cyst will enclose it there.

Then a new growth occurs within the vesicles, and by a process somewhat similar to budding, one or numerous bodies resembling the heads (or scolex) of a Tape Worm are developed. These, if they escape by the death of the animal, or by its being eaten by others, will become Tape Worms in the devourer. Thus the mouse, eating dirty substances, gets an embryo into its body, and the cat eats mouse and embryo; and the new growths within the last escape as the mouse is digested, and produce Tape Worm in the cat. Or the part of the embryo which is covered with the hooks becomes developed into a larger body, and has suckers and hooks differently arranged.

The embryo from the egg, which thus becomes encysted in the tissues of a vertebrate animal, is termed then a *Cysticercus*, and it forms one stage of a disease, producing "measles" in pork, for instance. The *Cysticercus* being swallowed by another vertebrate, the fore part of it, or the scolex, becomes the head or asexual part of a Tape Worm. Sometimes the cyst of the embryo grows to a considerable size, and then the scolices which bud from its inside are called *Echinococci*, and the cyst is a hydatid.

These *Echinococci* are, however, the product of a Tape Worm which infests the dog and wolf, and the eggs, by some means or other, are swallowed by men and animals and develop the truly dangerous hydatid disease of the liver and other organs. This Tape Worm belongs to the genus *Tenia* and to the species *T. echinococcus*.

Another species of *Tenia*, or Tape Worm, which is the Beef Tape Worm,* has the head without any coronet of hooks. It varies from fifteen to twenty-three feet in length, and the metameres, some hundreds in number, have the sexual organs fully developed in the 450th. The *Cysticercus* of this worm forms measles in oxen, and the scolex of course has no hooks. The Beef Worm is found in man, and calculations have shown that it may



HEAD OF ECHINOCOCCUS.
(After Huxley.)

* *Tenia mediocanellata*.

grow at the rate of seventy-two millimetres a day, and that thirteen metamereres may be produced in the same time.

The common Pork Tape Worm,* common in the intestines of man, looks like a long, soft, white, jointed thing, which, when alive, elongates and contracts readily. The scolex, or head, is armed with hooks and suckers, and the metamereres present water channels, one on each side, and joined above and below, besides egg glands and a uterus centrally placed and branching, and also the male elements. The embryo scolex forms the pork measles, and, being eaten by man, turns into the common Tape Worm of the intestines.

A *Cysticercus* lives in the mouse, and it produces *Tenia crassicoila* in the cat. The cause of the death of many sheep is a hydatid in the brain, called *Cœnurus cerebralis*, and this, when eaten by the dog, produces *Tenia cœnurus* in its intestines.

The genus *Bothriocephalus* contains foreign and Irish Tape Worms. Its segments or metamereres do not separate individually so as to become independent organisms. It is a broad worm, attaining twenty-five to seventy feet in length and an inch in breadth, and there may be 4,000 joints. In the genus *Tetrarhynchus* four proboscis-like tentacles exist, thickly set with hooklets, retracted near the suckers. The shorter Tape Worms (genus *Caryophyllus*) do not have the metamereres separable, and the head, or scolex, produces one only, which carries the reproductive organs.

ORDER TREMATODA.

These worms, many of which are called Flukes, are flat, rarely cylindrical, often bladder-like, broad, elongated creatures; they are not jointed, and are frequently leaf-shaped, and they have no vent.

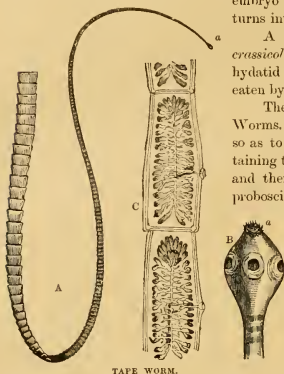
The Trematoda are parasitic within or outside animals, and whilst some grow from large eggs, laid

about the localities frequented by the parent, into the shape of the adult, others present the phenomena of alternation of generation, complicated by curious metamorphoses. These last kinds come from very small eggs which have got into water or damp places, and are at first very minute, contractile embryos, sometimes ciliated, and which endeavour to settle on some animal or other, ordinarily some of the Mollusca. This stage is that of the ciliated embryo. The ciliated embryo's office is to get on to a host; it then loses its cilia and becomes stationary on its host, and then gives exit to a cylindrical sac-like object, which has two lateral prolongations close to a tapering tail. At this stage of growth the parasite is called the *Redia*, and it has a mouth and a simple intestine, but no other organs. Within this bag-like *Redia* a process of budding goes on, each bud becoming a creature like the parent of the ciliated embryo in shape; but it is destitute of reproductive organs, and is furnished with a long flat tail like a Tadpole, by which it is propelled after the escape from the *Redia*. At this stage they are called *Cercariae*. They burst forth, and, after a free-swimming existence, penetrate the body of some animal. They drop their tails and become encysted in the tissues. Finally, they assume the adult form and develop reproductive organs within, out of which pass the eggs. The *Redia* acts as the "nurse," and the Trematode may pass through life by inhabiting two very different animals, after coming forth from that inhabited by the parent. The stages vary in different genera, and, as a rule, the first are passed in invertebrate and the last in vertebrate animals.

The first sub-order of the Trematoda is that of the *Distoma*, with not more than two suckers without hooks, and their *Rediæ* and *Cercariæ* live principally in Mollusca.

Distoma hepaticum and *D. lanceolatum* are species which have been found in the human liver. The first-named species also bears the generic title *Fasciola*, and is very common in the Ruminantia, and it

* *Tenia solium*.



TAPE WORM.

A, Piece of Tape Worm with small head (a) and metamereres gradually increasing in size; B, a, head with suckers and hooks; C, metamereres with ovarian apparatus.

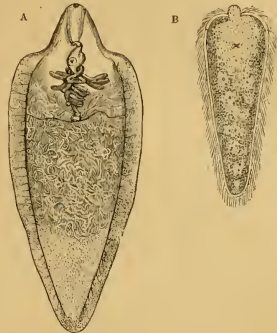
produces the "rot." The effects of allowing flocks of sheep to graze on low pastures, during continuous wet weather, are unfortunately too well known. The animals take in the parasite with their grass, or accidentally consume Mollusca which contain them.

In the genus *Amphistomum* the ventral sucker is close to the posterior end, and is deep. The species are found in the frog, ox, elephant, and many other animals.

The next sub-order or division of the Trematoda is that of the Polystoma, which are furnished with several suckers, the hindmost of which often have hooks. They are parasites on the outside of animals. The eggs are large, and there are no metamorphoses as a rule. In *Diplozoon*, two Polystoma are found united so as to form an X-like creature, and the hinder extremity of each is furnished with two rows of quadruple suckers.

ORDER TURBELLARIA.

These are lowly organised flat worms, which may be ribbon-shaped, leaf-shaped, or oval, broad, or long. They live free in water, and on land, are predaceous, and they have a mouth with or without a proboscis, and a simple or ramifying digestive tube. The skin is ciliated, and is highly sensitive. There are eye-spots and rudimentary organs of hearing in some. The anus is present in some, but not in others. The nervous system consists of two ganglia placed in the anterior part of the body, branches are given off, and a longitudinal cord extends backwards, and in some there are the rudiments of ganglia. In some Turbellaria the limits of the digestive tract are not distinguishable, and the food finds its way into a mass of internal cells. All have water-vessels which open externally by one or more pores, and are ciliated; and also "pseudo-hæmal" vessels, consisting usually of a median,

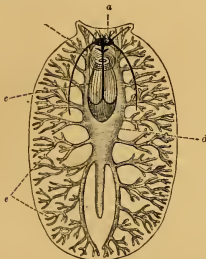


DEVELOPMENT OF LIVER FLUKE.

A, sexually mature (after Blanchard); B, embryo (after Leuck's E.).

a dorsal, and two lateral trunks, which unite in front and behind. The walls of these vessels are contractile, non-ciliated, and their contents are clear and uncoloured. One sub-order, the Nemertina, has ciliated grooves on the anterior part of the body, on the floor of which is a nervous structure. In most the embryo passes by insensible gradations into the form of the adult, and in some there is a metamorphosis. There are three sub-orders, the Rhabdocœla, the Dendrocœla, and the Nemertina or Rhynchocœla.

The Rhabdocœla are the simplest forms, and have a flat body with cylindrical or rod-shaped digestive organs, without a vent. They are carnivorous and suck the juice of small worms and entomostraca and insect larvæ which they envelop in a secretion. One family, the Opisthometidae, has a proboscis, coloured eyes, and calcareous particles connected with hearing. The family Convolutidae are long flat worms with chlorophyll in their tissues, and one of the species is a very active dweller between tide-marks in England. It swims well, yet it has no special senses. The Dendrocœla have a ramified intestine, and the long flat body has a proboscis. The Land Planarians have eyes, no tentacles, a proboscis, and a narrow body. They are found in the United Kingdom and generally in Western and Central Europe. They have been found in America, and on continental as well as on oceanic islands. Moseley states that they are nocturnal in their habits, and shun the light, getting under leaves. Some contain chlorophyll, and seek the light but die in the sunshine. They eat small snails, worms, and flies. An American kind secretes a mucous thread and suspends itself in the water, and another



DIGESTIVE APPARATUS OF EURYLEPTA SANGUINOLENTA.

a, nervous ganglion, or brain; b, mouth; c, pharynx; d, stomach; e, ramification of the digestive cavity.

lets itself down from the leaves by one. The Marine Planaria are found swimming in an undulating manner on the surface of the ocean, where they seem to live free. Darwin described one in 1844. Moseley describes them, in the East Indian Archipelago, as swimming in a lively manner. Others collect on the Gulf Weed; such are the Stylochidae, which have two small tentacles with eyes on them and on the head also. They swim in a rapid sinuous manner, and attack their prey at once. In this group the young undergo a metamorphosis, and in one stage greatly resemble a Rotifer.

The Nemertina are long, worm-like, proboscis-bearing, and marine; they have brittle bodies and a straight intestine with lateral cæca. The body is very extensile, and they live under stones, avoid light, and hunt their prey.

The Sea Long Worm (*Lineus longissimus*) is fourteen feet long and only two to four lines broad. The eggs of these give forth ciliated embryos, and they grow into a helmet-shaped body with a tuft of cilia. Certain cells enclose the digestive canal and give rise to a worm-shaped body—the future adult form. This fact links the group to the Echinoderms.

Worms lived in the geological ages, and certain markings in the old rocks are attributed to them. Trails and tracks of the Errantia, such as are termed Nereites and Phyllocites, are found in the Silurian rocks. The horny jaws of the Errant Annelida have been found in the Paleozoic formations, and largely in the upper Silurian of Wenlock. Burrows of worms occur in the Cambrian and Silurian age, such as Scolithes and Arenicolites, and the casts or the fecal matters of Annelida, are frequent in many rocks. Tubicolar Annelida of the extinct genera Cornulites, Ortonia, Serpulites, Spirorbis, Serpula, &c., are found from the Silurian to the latest geological deposits, but the genera usually became extinct with time, the last two still existing.

CLASSIFICATION.

TYPE VERMES.

CLASS ANNELIDA	.	.	.	.	Sub-class Chaetopoda	.	.	{ Order Oligochaeta.
								{ " Polychæta.
					" Hirudinea	.	.	
" GEPHYREA	.	.	.	.	.	.	.	{ " Gephyrea Inermia.
								{ " " Armata.
								{ " " Tubicola.
" ROTIFERA	.	.	.	.	.	.	.	{ Family Philodinidæ.
								{ " Brachionidæ.
								{ " Hydatinæ.
								{ " Floscularidæ.
" NEMATHELMINTHA	.	.	.	.	.	.	.	{ Order Nematoidæ.
								{ " Chatognatha.
" PLATHELMINTHA	.	.	.	.	.	.	.	{ " Cestoida.
								{ " Trematoda.
								{ " Turbellaria.

P. MARTIN DUNCAN.

THE PRICKLY-SKINNED ANIMALS (ECHINODERMATA).

Position of the *Echinodermata* in the Animal Kingdom—Characters distinguishing them from the other *Radiata*—Subdivisions of the Group—The Limestone Skeleton; its Various Forms—The Digestive Tube—The Nervous System—The Blood-vascular System—The Water-vascular System—The Body cavity and its Contained Corpuscles—The Various Forms of Echinoderm-larvæ—Direct Development of some Echinoderms in the Southern Seas—Distribution of the Group in Space and Time—The *Echinozoa*—Structure and Habits of Starfishes, Ophiurids, Urchins, and Holothurians—The Trepang fisheries of the Tropical Seas—The *Crinoidea*—Structure and Mode of Life of a Feather-star—The Palæozoic Crinoids, Cystids, and Blastoids.

THE Marine Invertebrata known as *Echinodermata** owe their name to the prickly nature of their skin, which is usually more or less thickly set with spines and granules of limestone. Such animals are the Sea-urchins, or Sea-hedgehogs (Fig. 14), the Starfishes (Fig. 1), Sand-stars, Brittle-stars (Fig. 11), Feather-stars (Fig. 19), Sea-lilies (Fig. 18), and the Sea-cucumbers (Fig. 17).

The Echinoderms constitute one of the three great groups of animals which were associated by Cuvier under the name *Radiata*. The especial characteristic of this division of the animal kingdom is the arrangement of the various organs of the body in a radiating manner around a central axis, in which the mouth is placed. The bilateral symmetry, so apparent in the *Articulata* and in the bivalve *Mollusca*, is not visible at first sight in such animals as a Starfish, a Sea-anemone, or a Jelly-fish. The younger stages of all these creatures, however, exhibit a more or less evident bilateral symmetry (Figs. 2-5, 7); and this is sometimes quite distinct in the adult animal (Figs. 1, 11, 14, 19), for a median plane can be found, with the parts of the body which lie on either side of it disposed symmetrically in relation to it. The body of an Echinoderm is also far more complicated in its structure than that of a Polype, or Jelly-fish. The digestive apparatus is entirely shut off from the body-cavity, and there are two separate systems of vessels ramifying through the body, which are either completely independent of the body-cavity, or only communicate with it by special openings.

On account of these and other striking features in their organisation, the Echinoderms were removed from the Radiate type by Leuckart, a proceeding which has met with almost unanimous acceptance among European naturalists. But the resemblance between Echinoderm larvæ and young *Ctenophora* is adduced as one amongst other reasons (by some American zoologists) for affirming that the type of Radiates constitutes an independent division of the animal kingdom, containing three equivalent classes—Echinoderms, Jelly-fishes, and Polypes.

On the other hand, there are considerable resemblances between certain Echinoderms, both larval and adult, and some of the lower worms; and after Leuckart's removal of the former from the Radiate type, they were thrown, together with the Wheel-animalcules, Tape Worms, Fluke Worms, &c., into one group—the *Annuloida*,† the name of which indicated the worm-like (Annelidan) affinities of some of its members.

Further investigation has shown, however, that this arrangement is not a satisfactory one, and at the present time the Echinoderms are regarded by most zoologists as forming a distinct primary division of the animal kingdom. Its chief subdivisions are indicated in the following Table.



Fig. 1.—*ASTROPECTEN IRREGULARIS*, A COMMON BRITISH STARFISH, SLIGHTLY REDUCED.
m, the madreporite.

* Greek, *echinos*, hedgehog; *derma*, skin.

† Latin, *annulus*, a ring; Greek, *eidos*, form.

SUB-KINGDOM ECHINODERMATA.

	Class	Order.	Genus.
ECHINOZOA	◦ Asteroidea	†	Astropecten, Solaster, Goniaster.
	* Ophiuroidea	Ophiurida	Ophiura, Ophiocoma, Ophiothrix.
		Astrophytida	Astrophyton, Gorgonocephalus, Euryale.
		<i>Palechinoidea</i>	<i>Palechinus</i> , <i>Archaeocidaris</i> , <i>Melowites</i> .
	Echinoidea	Desmosticha	Echinus, Cidaris, Asthenosoma.
		Clypeastrida	Clypeaster, Mellita, Echinocyamus.
		Petalosticha	Spatangus, Brissus, Pourtalesia.
	Holothuroidea	Apoda	Synapta, Chirodota, Molpadia.
		Pedata	Holothuria, Cucumaria, Psolus.
		Elasmopoda	Elpidia, Deima, Hydromon.
PELMATOZOA	Crinoidea	<i>Palaeocrinoidea</i>	<i>Actinocrinus</i> , <i>Gyathocrinus</i> , <i>Platycrinus</i> .
		Necrinoidea	Pentacrinus, Comatula, <i>Apiocrinus</i> .
	<i>Cystoida</i>		<i>Glyptospherites</i> , <i>Echinospherites</i> , <i>Caryocrinus</i> .
	<i>Blastoidea</i>		<i>Protremites</i> , <i>Granatocrinus</i> , <i>Codaster</i> .

The names of orders and genera which are extinct are printed in italics.

Exclusively marine animals, the Echinoderms remove limestone from its solution in the sea-water, and build it up into a skeleton of very varied shape and of very different degrees of complexity. This skeleton is least developed in the Sea-cucumbers, or *Holothuroidea*† (Fig. 17). The skin of these animals is very tough and leathery, with little limestone plates scattered about on it. Occasionally, however, the plates are more developed, and overlap one another so as to form a continuous covering all over the body (*Psolus*). Certain Sea-urchins (*Echinoidea*§) are also in the same condition, the body retaining its flexibility, but being at the same time protected from injury by its coat of mail (*Asthenosoma*||). In most of the Urchins, however, the body is enclosed in a shell, or "test," which is composed of numerous limestone plates, firmly united to one another by their edges, and supporting spines of the same substance (Figs. 14—16). Besides this external skeleton, there is also more or less of an internal skeleton, in the form of arched plates, pillars, or radiating partitions within the test. Five pairs of arched plates, which are known as *auriculæ*¶ (Fig. 15), are of especial importance, as they occupy a very definite position with regard to the vascular trunks that radiate from the oral centre. In the Starfishes and Brittle-stars they are represented by a double series of more or less arched limestone pieces, which form an internal skeleton in each arm, and are called the ambulacral ossicles (Figs. 9, 13, *ao*). The skeleton of an Urchin, then, is almost entirely external, while that of the Starfishes and Brittle-stars is chiefly internal; but in both these classes, and especially in the latter, there is also an external skeleton of limestone plates, which bears spines, and is sometimes very considerably developed (Figs. 9, 11). Yet another form of skeleton is met with among the Crinoids.** The successive joints which make up the arms of a Sea-lily (Fig. 18; Fig. 20, *Br.*), although practically external, are of a different nature from the pieces forming the test of an Urchin (Fig. 14), for they occupy an exactly contrary position with respect to the vascular systems. Neither do they correspond to the ambulacral ossicles of a Starfish-arm (Fig. 9, *ao*), although these, together with the test of the Urchin, are not altogether unrepresented in the Crinoids.

The digestive tube of all Echinoderms is distinct from the general cavity of the body. It may be of considerable relative length, and make complicated windings within this cavity, as in the Urchins, Holothurians, and Crinoid; (Fig. 16, *i*; Fig. 20, *u*); or it may be a short bag, without any other opening than the wide mouth, as in the Ophiurids†† (Fig. 12); or lastly, there may be a short and straight tube in the vertical axis of the body, with lateral extensions into the arms (Fig. 9, *pe*), as in the Starfishes.

The nervous system consists of an oral ring (Figs. 12, 20, *nr*), from which radiating cords proceed along the primary divisions of the body (Figs. 9, 12, 13, 21, *n*). Both the ring and the radial nerves originating in it are in very close relation to the cellular covering of the oral surface of the body, which is specially modified where the nervous tissue underlies it. This tissue consists of closely packed fibrils and minute cells connected with them; but there is no special arrangement of

* For convenience of reference these two groups together are often spoken of as the Stellerida.

† A good classification of the Asteroidea is still a desideratum.

‡ Greek, *holothourion*; *cidus*, form.

§ Greek, *echinos*, hedgehog; *cidus*, form.

|| Greek, *asthenes*, weak; *soma*, body.

¶ Latin, diminutive of *auris*, ear.

** Greek, *krinon*, a lily; *cidus*, form.

†† Greek, *ophis*, a snake; *oura*, a tail; *eidus*, form.

the latter into ganglia, the minute structure of the oral ring being identical with that of its radial extensions. But although anatomical investigation fails to reveal the presence of a brain, or even of a ganglion, yet the result of physiological research is to indicate that the oral nervous ring is the seat of a centralising influence, which proceeds outwards from it, and regulates the movements of the tube-feet—organs of which more or less use is made in locomotion.

Immediately within the oral nervous ring is an annular blood-vessel (Figs. 10, 12, 20, *ob*), from which radiating trunks extend (Figs. 9, 10, 12, 13, 21, *b*). It is connected with a more or less complicated network of vessels, which surrounds the digestive apparatus (Fig. 20, *ib*). In most Echinozoa* it also communicates, by means of a bundle of vessels that run nearly in the vertical axis of the body (Fig. 10, *cp*), with an aboral blood-vascular ring (Figs. 10, 12, *ab*), from which vessels (Fig. 10, *gr*) proceed to the generative organs. This vascular bundle (Fig. 10, *cp*) was formerly regarded as a heart, and has been described as performing rhythmical contractions. This, however, is very doubtful; while some authors go so far as to say that the organ in question is merely a gland with an excretory duct, which opens upon the aboral surface of the body, and is unconnected with any portion of the vascular system.†

The special feature in the anatomy of the Echinoderms is a set of tubes which communicate with the exterior, and serve the purposes both of respiration and of locomotion. It is known as the water-vascular system, and consists of an oral ring (Figs. 12, 20, *ur*) and radial extensions (Figs. 9, 12, 13, 20, *ur*), like those of the blood-vascular system, which lies immediately external to it. The radial vessels give off numerous lateral branches, which enter contractile processes of the body-wall, the tube-feet, or tentacles. In the Crinoids, which lie on their backs, with their mouths upwards, the tentacles are exclusively respiratory in function. But most of the Echinozoa live mouth downwards, and the tube-feet are used in locomotion. They are, in consequence, often spoken of as “the ambulacral‡ feet,” while the whole system of water-vessels is called the ambulacral system. In most Echinozoa its communication with the exterior is effected by a tube which starts from the water-vascular ring, and opens on the surface of the body by a sieve-like plate, the “madreporite”§ (Fig. 1, *m*). This water-tube, as we will call it, is sometimes known as the sand-canal, or stone-canal, on account of the limestone deposits in its walls. It lies close to the central plexus, and is bound up together with it in the same membranous sheath.

In most Holothurians and in the Crinoids there are one or more tubes depending from the water-vascular ring, and opening into the body-cavity, which communicates directly with the exterior (Fig. 20, *ut*); and as far as can be judged from the conflicting statements of different naturalists, these are the only Echinoderms in which there is a direct communication between the body-cavity and the exterior. Protoplasmic corpuscles of different kinds are dispersed in the fluid which it contains. Some resemble the white corpuscles of the blood of a vertebrate animal, while others exhibit more active changes of form, and put out long thread-like extensions of their substance. The body-cavity of an Urchin or Holothurian also contains granular masses, which are coloured with a brown substance that contains iron, and changes its tint under atmospheric influences, so that it is probably connected with the process of breathing. This function, however, is mainly performed by the water-vascular system. It contains minute red corpuscles, tinged with hæmoglobin, the oxygen-carrying material that colours the corpuscles of our own blood, and has also been detected in that of Molluscs, Crustacea, Insects, and Worms. The cilia lining the water-vessels keep up continual currents in their interior, and the circulation of the corpuscles which is due to these currents is increased by the contraction of the walls of the water-vessels, and by the continual motion of the tube-feet or tentacles, whether they be used for locomotion or not.

The sexes are distinct in most Echinoderms, and the fertilised ova generally pass through a complicated process of metamorphosis before assuming their adult form. They are hatched as uniformly ciliated free-swimming embryos, which gradually acquire a digestive tube with two openings. The cilia become restricted to one or more transverse ridges (Fig. 7), and the larva passes

* Greek, *echinos*, hedgehog; *zoon*, animal.

† These statements are probably erroneous. They are based almost entirely upon the results of injections, which are much less likely to give accurate results than the study of continuous series of thin sections through any organ and the structures connected with it.

‡ Latin, *ambulacrum*, a place for walking.

§ *Etym.*, pierced with small holes, like the coral known as *madreporæ*.

from the spherical condition into one which exhibits a very complete bilateral symmetry. Portions of the primitive digestive tube become cut off from it, and form closed "vaso-peritoneal" cavities (Figs. 2, 4, 6, *w*), which develop into the body-cavity and the water-vascular system of the mature Echinoderm. The latter system acquires a communication with the exterior by a water-tube, which opens on the dorsal surface of the body by a "water-pore" (Figs. 2, 6, *wp*), that eventually becomes the madreporite of the Echinozoa.

The forms assumed by the fully-grown Echinoderm larvæ are very various. In the Urchins (Fig. 2) and Ophiurids (Fig. 3) the dorsal region of the larva is produced into a sort of conical hump, while the ventral face becomes much excavated, and its edges are produced into four pairs of slender processes, or arms, which are symmetrically arranged around the mouth (Fig. 2, *m*). These arms are supported by a framework of limestone rods, which has somewhat the appearance of an inverted painter's easel, and is exclusively characteristic of the Urchins and Ophiurids. It has nothing to do with the skeleton of the mature Echinoderm, coming into existence before this makes its appearance, and disappearing as it attains its full development. The arms open and shut like the ribs of an umbrella during the movements of the larva, which is generally known as a "Pluteus." This name was given to it on account of its fancied resemblance to a painter's easel.

In the Crinoids, on the other hand, a somewhat complicated skeleton makes its appearance at a very early stage of embryonic life, the whole or greater part of which passes directly into the skeleton of the adult. But in the larvæ of Starfishes and Holothurians there is little or no provisional skeleton; and the rudiments of the skeletal system of the adult do not appear till the later stages of larval existence. The two ciliated bands at first encircling the Starfish larva gradually extend themselves, until they enclose nearly the whole of the upper and lower

Fig. 2.—PLUTEUS LARVA OF THE PURPLE EGG-URCHIN (*Echinus lividus*), SEEN IN PROFILE.

m, mouth; *a*, anus; *wp*, water-pore, or external opening of the water-tube, which leads into *w*, the rudiment of the water-vascular ring. (After Metchnikoff.)

halves of the body, so as to form two large crescentic shields. The larva in this condition exhibits complete bilateral symmetry, and is called "Bipinnaria."* Loops now appear in the outlines of the oral and anal shields, and gradually increase in length, so as to develop into a number of long slender movable arms, which stretch out from the larval body in various directions, bending and twisting in the most graceful manner, as they are not supported by limestone rods (Fig. 4). The continual play of these arms not only assists in the locomotion of the larva, but also produces currents in the water which set towards its mouth. This stage of the Starfish larvæ is known as the "Brachiolaria";† and the development of the adult Echinoderm from it or from a Pluteus takes place entirely at the hinder end of the larval body. Rudiments of tentacles appear on the growing water-vascular ring, which is situated at the left side of the larval stomach, while the first traces of the permanent skeleton show themselves on its right side, near the dorsal pore of the water-vascular system. The remainder of the larval body gradually shrivels up and disappears, its substance going to feed the growing Echinoderm. This is well shown in Fig. 4, which represents a Brachiolaria with the Starfish disc developed at its anal extremity, some of its arms having been already absorbed. A similar process goes on in the case of the Pluteus

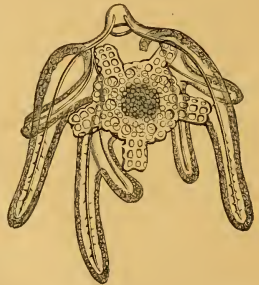


Fig. 3.—*Pluteus paradoxus*, THE ADVANCED LARVA OF AN OPHIURID, WHICH CONTAINS THE RUDIMENTS OF THE DISC AND RADIAL SKELETON OF THE ADULT, TOGETHER WITH THE LIMESTONE FRAMEWORK THAT SUPPORTS THE ARMS OF THE PLUTEUS. (After J. Müller.)

* Latin, *bis*, twice; *pinna*, a feather.

† Latin, *brachidium*, diminutive of *brachium*, an arm.

larvæ (Figs. 2 and 3). The young Urchin or Ophiurid gradually encroaches upon the Pluteus to such an extent that it forms an essential part of the body, the arms and rods seeming to be mere appendages, which ultimately disappear altogether.

The development of the young Holothurian from its larva is much simpler than that of the other Echinozoa. There is but one continuous longitudinal ciliated band around the bi-lateral larva (Figs. 5, 6, c), instead of two, as in Bipinnaria; and this does not throw out long processes, but only becomes deeply sinuated. Certain parts of the sinuated portions of opposite sides become united together, while others are obliterated, so that the larva, which has become barrel-shaped, is surrounded by a number of transverse ciliated rings. These in their turn disappear, the body of the larva elongates, and tentacles appear round the mouth, while the water-tube usually loses its connection with the exterior by the dorsal pore (Fig. 6, *wp*), and depends freely from the water-vascular ring into the body-cavity, into which it opens. But the amount of metamorphosis which the larva undergoes is not considerable, as it has no appendages to be resorbed into the body of the adult.

There is still less metamorphosis in the development of a Crinoid. The cilia, which appear at first over the whole surface of the embryo, become restricted, before it is hatched, to four transverse bands and a tuft at its hinder end (Fig. 7), while the embryo becomes slightly curved, somewhat like a kidney-bean. In its concave surface, which is turned downwards, is the single opening of its digestive canal, corresponding to the anus of a Bipinnaria. The larva gradually increases in length, and delicate limestone plates make their appearance near its front end, arranged in two cross-rings of five plates each. The plates of the lower ring, which are called the basals, rest upon the top joint of a short stem, composed of delicate rings of limestone. At this stage the larva has the form of a bent club or rod, with an enlarged head,

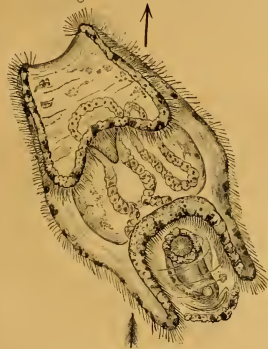


Fig. 5.—LARVA OF HOLOTHURIA TURULOSA IN ITS NATURAL POSITION.

The arrow indicates the axis of rotation. The mouth at the upper and the anus at the lower end are connected by a short digestive tube, on the upper side of which is seen the rudimentary water-vascular ring. The cilia are arranged in a sinuated band. (After Schmidt.)

advanced to look after themselves. In Urchins, Starfishes, and some Holothurians, the nursery or brood-pouch is outside the body of the parent. In some Urchins, for example, a kind of open tent is formed in the neighbourhood of either mouth or anus by the approximation of two or three rows of spines. In



Fig. 4. — SIDE VIEW OF THE ADVANCED BRACHIO-LARIA LARVA OF A STARFISH (*Asterias vulgaris*).

The whole of the terminal part of the larva has been absorbed into the disc of the growing Starfish (or, the oral extremity alone, with its adjacent arms, retaining its original shape, is, one of the vaso-peritoneal tubes, from which the body-cavity and the water-vascular system are developed. (After A. Agassiz.)

which becomes the body of the future Crinoid. The permanent mouth appears in the centre of the upper ring of plates, which are consequently termed the "orals." They are gradually carried away from the cup formed by the basals by the appearance, between the two rings of plates, of the rudiments of the arms, which grow outwards as rapidly elongating processes. The advanced Crinoid larva is known as a "Pentacrinoid" (Fig. 8, B), owing to its resemblance to *Pentacrinus*,* one of the Sea-lilies. The development of a Crinoid is thus much more direct than that of a Starfish or Urchin. There is no metamorphosis, and either the whole of the larval body passes directly into the adult, or the stem is discarded, and the cup with the arms attached leads an independent existence. This is the case with the Feather-star (Fig. 19), which separates itself from all but the top joint of its stem, and anchors itself by little clawed hooks, or cirri, that appear upon this joint (Fig. 8, B; Fig. 20, *ci*).

A still more direct mode of development occurs among most of the Echinozoa of the Southern and sub-arctic Seas, which produce no free-swimming ciliated embryos at all. But the young develop directly, either within or upon the body of the parent, where they are protected until sufficiently

advanced to look after themselves. In Urchins, Starfishes, and some Holothurians, the nursery or brood-pouch is outside the body of the parent. In some Urchins, for example, a kind of open tent is formed in the neighbourhood of either mouth or anus by the approximation of two or three rows of spines. In

* Greek, *pente*, five; *krinon*, lily.

a large Starfish dredged by the *Challenger* in the Southern Seas, a sort of tent is formed in the middle of the upper surface of the body, which consists of five membranous valves supported by spines. These valves can be raised or drawn together so as to form a low pyramid; and the eggs pass directly from the ovaries into its cavity, where they assume the form of young Starfishes, without previously passing through the Bipinnaria and Brachiolaria stages. In another species the spines covering the back have flattened heads, which fit closely together, so as to cover in the arcade-like spaces left between their shafts. The young develop within these spaces, eventually pushing their way out by forcing the spines aside. A similar nursery is formed on the back of a South Sea Holothurian (*Psolus*) by the apposition of the heads of mushroom-shaped plates; while in another species from the Falkland Islands there is no special nursery, but the young come to be packed into two continuous fringes adhering to the two rows of tube-feet along the back, which are imperfectly developed, and are not used for locomotion. In one South American Holothurian, however, the young are protected within the body of the mother, one individual having yielded sixteen young ones measuring $\frac{1}{8}$ " in length. In the viviparous Ophiurids, the nursery, though internal, is not a portion of the body-cavity, but a pouch which opens externally and projects into the body-cavity, serving also at the same time as a breathing apparatus. There are usually ten of these pouches, though as many as fourteen have been found in one individual, each containing three young Brittle-stars.

Fig. 6.—DIAGRAM OF A SIDE VIEW OF THE HOLOTHURIAN LARVA REPRESENTED IN FIG. 5.

m, mouth; g, gullet; s, stomach; a, anus; c, longitudinal ciliated band; ac, acrocardium of water-vascular ring; wpp, water-pore; rp, right and left peritoneal cavities, from which the water-vascular system is developed. (After Seeluck.)

seas. They have also a wide bathymetrical range, extending from between tide-marks to some of the greatest depths explored by the dredge, where they are chiefly represented by the Ophiurids. There are certain forms in each class which are especially characteristic of the abyssal depths, and have a very extensive distribution. Thus most deep-sea Holothurians belong to a very remarkable section of the group, the *Elasmopoda*,* which look singularly like nudibranchiate Mollusca. The Stalked Crinoids are also characteristic of the greater depths, some of them being the last survivors of a large and important group (*Apiocrinus*†) which flourished in the Mesozoic Seas. Similarly, the more prominent abyssal forms among the Sea-urchins are chiefly those which have a flexible test (*Asthenosoma*), instead of a shell of immovable plates. They belong to a very singular group, which was believed to have become extinct after the deposition of the white chalk. Among the Starfishes and Ophiurids, again, the same generic types inhabit the great ocean depths in all parts of the world; but they are not so interesting in their palæontological relations as the Stalked Crinoids and the flexible Urchins.

Fossil Echinoderms occur in most of the stratified rocks from the Upper Cambrian upwards. Certain Palæozoic limestone beds are almost exclusively composed of crinoidal remains. The Stalked Crinoids were most abundant during the Palæozoic period, during which the Cystids‡ and Blastoids§ also flourished, to become extinct at or before its close. But the free Crinoids (*Comatula*||) are probably more abundant at the present time than in any previous geological period. Starfishes are among the earliest known Echinoderms, and appear to have gone on increasing in importance from the Cambro-Silurian period until the present day. Little is known of the fossil



Fig. 7.—DORSAL VIEW OF THE LARVA OF THE ROSEY FEATHER-STAR (*COMATULA ROSACEA*) SHORTLY BEFORE THE DISAPPEARANCE OF THE CILIATED BANDS. MAGNIFIED TWENTY TIMES. (After Wyville-Thomson.)

* Greek, *clauuo*, to move; *pous*, foot.

† Greek, *kustis*, a bladder; *eidos*, form.

‡ Greek, *apion*, a pear; *krinon*, a lily.

§ Greek, *blastos*, a bud; *eidos*, form.

|| Latin, *coma*, hair; and the obsolete form, *tulo*, I bear.

Ophiurids, which commence with the same period. The Urchins are represented in the Lower Silurian by a single aberrant form, but more appear in the later Palæozoic beds; while the Mesozoic and Tertiary rocks contain a great variety of types. Fossil remains of the soft-bodied Holothurians are naturally rare, but they can be traced as far back as the Carboniferous period.

The Echinoderms fall into two very natural groups: viz., (1) the *Echinozoa*, including the Urchins, Stellerids,* and Holothurians, all of which crawl about by the aid of their tube-feet, with the mouth downwards or at one end of the elongated body; and (2) the *Pelmatozoa*,† or Stalked Echinoderms. In the latter group the dorsal region of the body is produced into a stalk, by which the animal fixes itself with its oral surface upwards (Figs. 8, 18). In the Feather-stars, which form the majority of recent Crinoids, the stalked condition is a temporary one (Fig. 8), the body eventually detaching itself from the larval stem, and settling down on its own account, though still in the same relative position, i.e., with its oral surface upwards (Fig. 19). Nearly all the fossil Crinoids were stalked, as were also the extinct *Blastoidea* and *Cystoidea*, though a few sessile forms are known.

Among the *Echinozoa*, the Stellerids are those of which the anatomy is most completely known; and as the members of the two classes to which this name is applied resemble one another in very many respects, it will be convenient to take them as the starting-point of our investigations into Echinoderm structure.

(1) *Asteroidea*.‡ The body of a Starfish is usually somewhat flattened, and either pentagonal in outline or more or less stellate, in which case it is said to consist of a central disc extended into five or more arms (Fig. 1). Its shape is maintained by an internal skeleton of limestone joints (Fig. 9, *ao*). This is covered, though not closely, by a tough leathery skin, in which are embedded granules and plates of limestone, many of them bearing spines. Some of the spines, which are known as paxillæ, assume the form of a stem with an expanded brush-like end (Fig. 9, *pax*). The mouth occupies the centre of the under surface of the body, and a deep groove, the "ambulacral groove," proceeds from it along each of the arms (Fig. 9, *ag*). This groove is nearly filled with the tube-feet, or tentacles (Fig. 9, *t*), which are connected with the ambulacral or water-vessel, situated in the middle line of the arm (Fig. 9, *w*), and are largely used in locomotion. Appended to each of the lateral branches of the water-vessel that proceed to the tube-feet is a minute muscular water-sac, or ampulla,§ by the contraction of which water is driven into the tube-foot so as to expand it. The tube-feet themselves are also contractile, and when several of them which are attached to any object by their terminal suckers are made to contract, the result is that the body is slowly drawn towards the fixed point. Other tube-feet are then distended and projected forwards, to take fresh hold farther on, while those previously fixed are detached by water entering them from the ampullæ, and so the movement goes on. The radial water-vessels all communicate with an oral ring provided with water-sacs, the "Polian vesicles,"|| which are similar to those in the arms, but do the same work on a larger scale. They are attached to the water-vascular ring between the origins of the radial trunks; and the single water-tube which communicates with the exterior by the madreporic plate (Fig. 1, *m*) occupies a similar interradial position. It is enclosed in a common sheath with the central plexus of the blood-vascular system (Fig. 10, *cp*), which unites the oral blood-vascular ring (*ob*) with the aboral ring (*ab*), connecting the ten genital and the two gastric vessels (*gc*; *pb*). Radial trunks (Figs. 9, 10, *b*) proceed outwards from the oral ring beneath the water-vessels, and send minute



Fig. 8.—PENTACRINOID LARVA OF THE ROSEY FEATHER-STAR (*Comatulna rosacea*).

A, quite young, before the opening of the cup; and the appearance of the radial plates; B, nearly mature with five arms upon the top stem point; b, basis; o, orals; r, first radials.

* Latin, *stella*, a star; Greek, *eidos*, form.

† Greek, *pelma*, a stalk; *zoon*, animal.

‡ Greek, *aster*, a star; *eidos*, form.

§ Latin, *ampulla*, a flask.

|| Named after Poli, the anatomist who discovered them.

branches to the successive tube-feet (Fig. 10, *b f*). External to the blood-vessels are the radial nerves (Fig. 9, *n*), communicating with an oral nervous ring, and sending off very minute tentacular branches. Each nerve terminates at the bent-up extremity of the arm in a pigmented spot, containing clear lens-like bodies, and serving as an eye. Close to it is the terminal tentacle of the arm, which has no sucker, but is excessively sensitive, and appears to be a very delicate organ of touch.

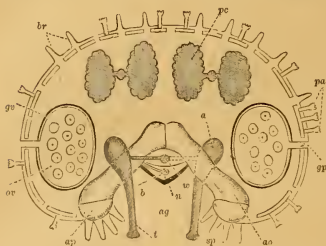


Fig. 9.—DIAGRAMMATIC REPRESENTATION OF A CROSS-SECTION OF AN ARM OF THE COMMON CROSS-FISH (*Asterias rubens*).

On the left side the section is supposed to pass between two of the ambulacral ossicles, but on the right side through one of them (ao); ag, ambulacral groove; a, radial nerve; b, radial blood vessel; w, radial water-vessel; a, ambulacral ossicle; n, tentacle; ap, adambulacral or lateral plates; sp, spines; paz, paxilla, springing from irregular limestone plates; ov, ovary; gp, genital pore; go, genital blood-vessel; br, gills; pc, pyloric caeca.

centre of the aboral face of the body. Breathing is carried on partly by the tentacles of the water-vascular system (Fig. 9, *t*), and partly by thin-walled tubular processes of the external skin (Fig. 9, *br*), which are ciliated internally, and are in direct communication with the body-cavity; so that a free interchange of gases can take place between the water which they contain and that which bathes their external surface.

The paired genital glands are situated interradially at the junction of the body with the arms, into which they extend for a greater or less distance (Fig. 9, *ov*). Each gland is divided into a number of berry-like clusters, which communicate with the exterior by one or more genital pores. These are either situated in the angles between the arms, or, in the case of the more elongated glands, upon the arms themselves (Fig. 9, *gp*).

The internal skeleton of each arm consists of two longitudinal series of plate-like joints, the "ambulacral ossicles" (Fig. 9, *ao*), which lean against each other in the middle line above, so as to form the sides and roof of the ambulacral groove (ag). Between each ossicle and those in front and behind it are small pores, produced by the fitting together of notches upon the front and back faces of the successive joints. The branches from the radial water-vessels (*w*) to the tube-feet (*t*) pass outwards through these pores. The lower ends of the ossicles abut against a series of short and thick "adambulacral plates" (Fig. 9, *ap*), which form the edges of the groove, and usually bear spines (*sp*); while the sides of the arms are protected by a variable number of lateral or marginal plates, also bearing spines (Fig. 1). In some cases also there is an external skeleton of well-defined plates on the upper surface of the arms, but there is generally only a mere network, more or less regularly arranged, and bearing clustered spinelets, or paxillæ (Fig. 9, *paz*).

Attached to some of the larger spines, and in the intervals between them, are numerous little

The mouth leads by a short gullet into a wide stomach, the lower part of which is produced in the direction of the rays into five large sacs with folded walls. Above the origins of these sacs the stomach suddenly narrows, and then enlarges into a pentagonal cavity, from the angles of which five forked tubes extend into the rays. Each fork is the stem of a long tree-like mass, which is formed of dense branches of from four to six pear-shaped follicles, all connected with the central stem. These pyloric caeca, as they are called (Fig. 9, *pc*), are supposed to represent the liver of the higher animals. The pentagonal cavity into which they open leads into a short tubular intestine, that usually terminates in a minute anal pore, situated near the

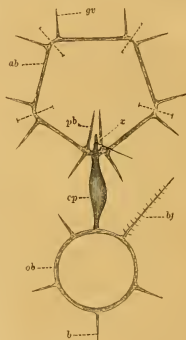


Fig. 10.—DIAGRAM OF THE BLOOD-VASCULAR SYSTEM OF A STARFISH. (After H. Ludwig.)

cp, central plexus; z, its dorsal extremity; ab, aboral blood-vascular ring; gu, genital vessels; pb, gastric vessels; ob, oral blood-vascular ring; b, radial blood-vessel; b', its tentacular branches.

flexible stalks, each terminating in a pair of pincers. These are opened and shut by special muscular fibres, and are in a state of continual movement, twisting about, and snapping at minute things which come in their way. They are known as "pedicellariæ,"* but their precise functions are not very clear. It has been suggested that they may perhaps act as scavengers, catching up particles of dirt from the surface of the body, and casting it off into the surrounding water.

The Starfishes are excessively voracious animals, feeding indifferently upon shell-fish, crabs, anemones, worms, and all kinds of carrion. Oysters and other bivalves have but little chance against them. The Starfish enfolds the shell with its arms, and protrudes the lower portion of its stomach through its mouth and between the valves of the shell, until it can seize upon the body of its unfortunate occupant. Little by little the great stomach is pushed farther and farther out of its own body and over that of its prey, until at last, if the oyster be a large one, the pouches are withdrawn from the rays, and the Starfish is substantially turned inside out. This work of destruction is sometimes carried on by a number of Starfishes interlacing their arms together, so as to form a ball, which rolls about in the water with the clams, oysters, or other shell-fish in the middle of it. Starfishes are thus very dangerous enemies to the cultivation of oysters. In some places they are so abundant as entirely to prevent any oysters growing at all. The damage done by them on the coast of the United States, between Cape Cod and Staten Island, is estimated at over 100,000 dollars yearly. They sometimes invade the oyster-beds in enormous hordes, coming quite suddenly at intervals of a few years. Such an invasion came to Providence River, Rhode Island, United States, about the year 1860, and caused a loss to the oyster-growers of 150,000 dollars. At another locality 2,500 individuals were speared on an oyster-bed in two days.

When Starfishes were first discovered to be enemies to oyster culture the captured ones were torn across and thrown back into the sea, though not to die; for Starfishes, like all Echinoderms, have a considerable power of reproducing lost parts, a single arm having been known to grow up into a new Starfish. Consequently, instead of diminishing the pest, the above method of procedure would tend to directly increase it, two or three new enemies being made out of every captive. Now, however, the oystermen hand their captures over to the gardeners, by whom Starfishes are much valued as manure. The common Crossfish (*Asterias rubens*) is largely used for this purpose on both sides of the English Channel, and also in the Eastern Counties. This species is also known as Five-fingers, Five-fingered Jack, and the Devil's-fingers or the Devil's-hands, these latter names being used upon some parts of the Irish coast, where a Starfish is looked upon with superstitious dread.

(2) *Ophiuroidea*. The name of this class is derived from the three Greek words: *ophis*, snake, *oura*, tail, and *eidos*, form, and refers to the external form of these creatures (Fig. 11). They have longish serpent-like arms attached to a relatively small and usually rounded body or disc, to which the viscera are confined. The top and sides of the disc generally bear plates or scales of various sizes; and they are often more or less covered with limestone granules, spinelets, or even with groups of spines. The precise mode of arrangement of the plates on the top of the disc varies in different species; but five pairs of plates, known as the "radial shields" (Fig. 11, *rs*), are always present, though not always visible. Each pair corresponds to the base of one of the arms or rays, one plate lying on either side of the ray, not far from the edge of the disc. This is usually, but not always, notched for

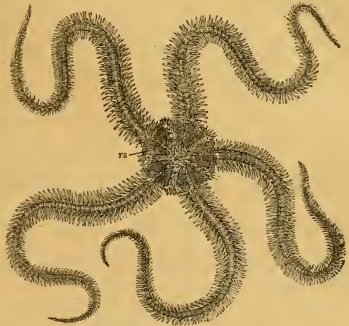


Fig. 11.—COMMON BRITTLE-STAR (*Ophiothris fragilis*).
Natural size. *rs*, radial shields.

* Latin, diminutive of *pedicellus*, a louse.

The arms of the Ophiurids are rather appendages to the body (Fig. 11) than actual portions of it, as is the case in the Asterids (Fig. 1). The greater part of each arm is formed by a central bony axis, which is composed of successive joints, and fills up almost the whole of the internal cavity of the arm. Each of the quadrate axial ossicles (Fig. 12, A^6 ; Fig. 13, ao) consists of two lateral halves, which are united in its middle line, and represent the smaller and less-developed ambulacral ossicles in the arm of a Starfish (Fig. 9, ao). The successive ossicles are connected by pairs of strong muscular bundles, and articulate by tenon and mortice joints upon their terminal surfaces.

Corresponding to each ossicle of the internal skeleton are four superficial plates, viz., the "lower arm-plate" (Fig. 12, s^2 ; Fig. 13, l), the upper "arm-plate" (Fig. 13, u), and two "side arm-plates" (Fig. 13, s). These plates are often more or less covered with spines, as is shown in the specimen figured (Fig. 11). On either side of the under arm-plate, between it and the side arm-plates, are openings by which the tube-feet reach the exterior. Each opening is protected by a little scale or scales, which may be upon the side arm-plate, or upon the lower arm-plate, or upon both.

The tube-feet have less to do with locomotion than their fellows in the Urchins and Starfishes, as they have no terminal suckers, but they are very sensitive to touch. Their chief function is probably respiratory, while locomotion is effected by means of the worm-like arms, which are capable of a very considerable amount of lateral movement, though they cannot be bent to any great extent. The Ophiurids are much more active than the Asterids, and of them the Brittle-stars are more so than the Sand-stars, seldom remaining quiet for a moment, but keeping their arms in a state of continual twisting movement. They also have a singular power of breaking their arms into fragments, which are often flung away to some little distance from the disc, new ones growing out from it again after a longer or shorter interval, for the power of reparation which these animals possess is very considerable.

Most of the *Ophiuroidea* have simple and undivided arms (*Ophiurida*, Fig. 11); but in the members of the order *Astrophytida** the arms fork ten or twelve times, and the numerous branches into which they divide interlace with one another, so as to form a sort of trellis-work all round the disc. These creatures are variously known by the names of Basket-fish, Medusa-head Starfish, and Argus.

The habitat of the Sand-stars may be gathered from their name, while the Brittle-stars are to be found both on a sandy bottom and in the rock-pools on the shore. Many of them are very abundant in the neighbourhood of oyster-beds and scallop-banks, and are largely preyed upon by the cod and other fish, while their own stomachs are full of minute foraminiferal shells.

(3) *Echinoidea*. The members of this class are variously known as Sea-eggs, Sea-hedgehogs, or Sea-urchins. The last name, used as it often is without the prefix, is merely a corruption of "Oursin," the French word for hedgehog. This appellation is not bestowed without reason, the body of any common Echinid being more or less globular and covered with spines. These spines are jointed on to knobs or tubercles, which are borne by the closely-fitting limestone plates of the test or shell (Fig. 14, A, B). The tubercles do not, however, cover the whole surface of the test indiscriminately, but they are chiefly disposed in five broad zones, which extend from one pole to the other. Alternating with these are five narrower zones, which bear smaller and fewer tubercles, and are pierced with small holes arranged in regular rows. Through these holes the Urchin extends its tentacles or tube-feet, which are provided with terminal suckers, like those of the Starfishes, and are largely used in locomotion, especially when the creature is climbing a steep slope. On level surfaces, however, the spines are also brought into play, the animal advancing by a sort of tilting motion.

Scattered among the spines are pedicellariæ, resembling those of the Starfishes, except that they have three prongs instead of two (Fig. 14, C, D). They are said to be used in climbing for laying hold of fronds of seaweed, and so enabling the Urchin to steady itself until it can make use of its sucking feet. They are also employed as scavengers, those round the anal opening laying hold of the ejected

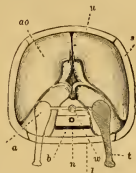


Fig. 13.—DIAGRAM ON A CROSS-SECTION OF AN OPHIURID ARM (slightly altered from Sladen).

ao , ambulacral ossicle; u , upper arm-plate; l , lower arm-plate; s , side arm-plate; a , radial nerve; b , radial blood-vessel; w , radial water-vessel; o , ampulla; t , tentacles.

* Greek, aster, star; *phuton*, plant; *eidos*, form.

remains of the food, and passing them on to those below. These, in their turn, close upon the particles, and pass them down the sides of the body until they can drop off into the water without becoming entangled among the tentacles and spines.

Each of the narrow poriferous zones in the test of an Urchin is spoken of as "ambulacral," owing to its being pierced for the passage of the tentacles of the ambulacral system; while the five

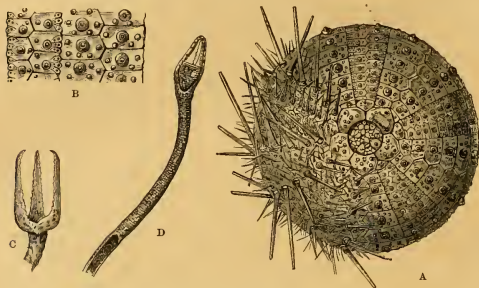


Fig. 14.—GENERAL VIEW OF THE TEST OF AN URCHIN (*Echinus microstoma*), FROM ABOVE. NATURAL SIZE. (After Wyville Thomson.)

A, Most of the spines have been removed. The madreporite is seen on the genital plate lying N.E. of the centre.
B, Portions of the ambulacral and interambulacral zones in the test of *Tropopneustes variegatus*. Enlarged. (After Agassiz.)
C, Head of Pedicellaria with the valves open. (After Bird.)
D, Pedicellaria with the valves closed. (After Valentin.)

plates. The periproct is separated from the apices of the ambulacral and interambulacral zones by two rings of larger plates alternately arranged (Fig. 14, A). Those of the inner ring, which terminate the interambulacral zones, are pierced by the ducts of the genital glands. One of them, that occupying a N.E. position in the figure, is pierced by the water-pores, and thus represents the madreporite which is at the upper extremity of the water-tube of the Starfish (Fig. 1, m). The plates of the outer ring are pierced by the unpaired tentacles, which terminate the water-vascular trunks, and represent the "ocular tentacles" at the ends of the Starfish arms.

In the regular Urchins (*Desmosticha*) the mouth and anus are at opposite poles of the vertical axis of the shell; but either one or both may be more or less excentric. In the *Clypeastrida*† (Cake-urchins) the anus is near the margin of the dorsal surface, while in *Spatangus*§ (Heart-urchin or Sea-bun) and its allies the anus is marginal, or even on the under-surface of the test, in which the mouth may also occupy a more or less excentric position.

In the *Desmosticha* and *Clypeastrida* the mouth is provided with a very complicated masticating apparatus, which attains its highest development in the former group. It consists of twenty principal pieces arranged into a five-sided conical mass, which was aptly compared by Aristotle to a lantern (Fig. 15, A, B). In the centre of the whole are five teeth working in bony sockets, or pyramids, that are connected by muscles with one another, with the interior of the test, and with the arched auriculæ already



Fig. 15.—A, INTERNAL VIEW OF THE TEST OF *Echinus microstoma*, SHOWING THE DENTAL PYRAMID OR LANTERN OF ARISTOTLE IN THE CENTRE OF THE RING OF AURICULE, NAT. SIZE; B, THE DENTAL PYRAMID. (After Wyville Thomson.)

* Greek, *desmos*, a band; *stichos*, a row.

† Latin, *Clypeus*, a shield; Greek, *astr*, a star; *eidos*, form.

‡ Greek, *peri*, round about.

§ Greek, *spatangos*.

mentioned, which are well shown in Fig. 15, A. Two other sets of accessory pieces connect the pyramids together, and serve as attachments for muscles, the number of these organs which are concerned in moving the whole lantern being thirty-five.

The teeth move concentrically around the opening of the gullet (Fig. 16, *g*), which passes upwards through the lantern, and is continued into an elongated digestive tube (Fig. 16, *i*). This exhibits no differentiation into stomach and intestine, but is coiled spirally around the interior of the test, to which it is attached by a mesentery. It is accompanied by two blood-vessels, the one dorsal and the other ventral, which are connected with one another by an extensive vascular network in its walls. The ventral vessel arises from an oral ring, which is situated, together with the water-vascular ring, on the upper surface of the lantern. It is probably (though we do not as yet know with certainty) connected with an aboral ring, from which the vessels supplying the genital glands are given off, and in which the dorsal intestinal vessel may perhaps arise. The central plexus is in intimate relation with the water-tube which descends from the madreporite to the water-vascular ring. This last usually bears five Polian vesicles, and gives off the radial vessels, which descend the sides of the lantern, and then pass outwards beneath the arches of the auricles (Fig. 16, *p*, *po*). The bases of the lateral tentacular branches which they give off open into large ambulacral vesicles, just as in the Stellerids. These radial water-vessels are accompanied by the radial blood-vessels and nervous trunks. The latter start from an oral ring, which is not above the lantern as the vascular rings are, but is close down upon the buccal membrane lying between the gullet and the tips of the teeth, which project from the lantern. The tentacular branches of the radial nerves pass outwards through the same pores in the ambulacral plates as the tentacles themselves, and also communicate with an extensive nervous network, which penetrates the delicate membranous layer surrounding the test, and furnishes nerves to the pedicellariæ and spines.

In most of the regular Urchins there are ten gills in the neighbourhood of the mouth. These are thin-walled ciliated extensions of the closed body-cavity, which protrude between the buccal membrane and the lowest plates of the test, and assist in the work of respiration. In the irregular Urchins this function is exclusively performed by the water-vascular system, and some of the tentacles are specially modified, becoming broad, flat, and somewhat lobed. These are often spoken of as ambulacral gills.

The genital glands of the Urchins are situated in clusters beneath the aboral portion of the test, and communicate with the exterior by the pores in the genital plates.

All the Urchins are gregarious, and many of the Desmosticha inhabiting coasts that are much exposed to the action of the waves protect themselves by hollowing out cavities in the solid rock, even in granite. This is the case with the purple Egg-urchins of the English coast. They chisel out the rock with their teeth by incessantly turning round and round, commencing when young, and continually enlarging their prison to allow for the growth of their test and spines. The irregular Urchins, on the other hand, mostly prefer quiet sandy places, where they can bury themselves.

(4) *Holothuroidea*. The Holothurians, which are also known as Sea-cucumbers, Trepangs, or Bêches de Mer, are the most worm-like and the least radiate in form of all the Echinoderms. They have more or less elongated bodies (Fig. 17) enclosed in a tough skin, which contains only a comparatively small amount of calcareous matter; and this (except in rare cases) never forms a continuous armour of plates, but occurs only in the shape of scattered grains, which often assume very definite and regular forms. There may, however, be a ring of limestone plates around the gullet, five of which have the same relation to the radial water-vessels as the auricles

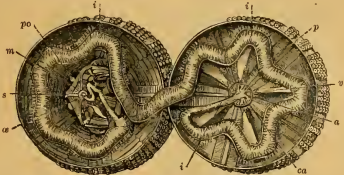


Fig. 16.—VIEW OF THE INTERIOR OF THE DISSECTED TEST OF THE PURPLE EGG-URCHIN (*Echinus lividus*).

g, gullet; *i*, intestine; *a*, anus; *p*, a water-vessel; *po*, oral end of another; *ca*, ocular plate; *z*, one of the pieces of the dental pyramid; *m*, one of the jaw muscles; *v*, ovary. (After Friedmann.)

within the test of an Urchin, and also serve the same purpose, viz., the attachment of muscles. These organs are disposed in five bands, which correspond in position with the radial nerves proceeding from the oral ring. The mouth is at one end of the body, and the gullet leads into a long and much coiled digestive tube of tolerably uniform width, which terminates in a large pouch or cloaca, at or near the opposite extremity.

Around the mouth is a fringe of branched tentacles (Fig. 17) connected with the water-vascular ring. In a few species this ring communicates directly with the exterior by means of a



Fig. 17.—HOLOTHURIAN (*Cucumaria planici*) WITH ITS BUCCAL TENTACLES EXPANDED. TWICE NATURAL SIZE.

water-tube opening upon the surface of the body. But in most Holothurians the water-tube hangs down freely into the body-cavity, and terminates in a sieve-like madreporite. One or more Polian vesicles are attached to the water-vascular ring in the intervals between the origins of the radial vessels, with which tube-feet provided with ampullæ are connected. In some forms (*Cucumaria*)* these tube-feet are evenly distributed, and almost equally developed on all the radial vessels (Fig. 17); but in others (*Psolus*) they are confined to three out of the five vessels, that are arranged in a flat sole-like disc, on which the animal creeps. In the *Elasmopoda* the two lateral vessels of this under surface are the only ones in the body, the three remaining vessels being suppressed; while in *Synapta*† and its allies there are no radial vessels at all, the oral ring and the tentacles connected with it being the sole representatives of the water-vascular system.

The blood-vascular system consists essentially of dorsal and ventral vessels along the digestive tube, as in the Urchins. These are connected with an oral plexus, from which the radial blood-vessels originate. But no representative of a "central plexus" has yet been made out, except in the *Elasmopoda*, in which the two extremities of the dorsal vessel are united by a large contractile trunk.

Respiration is largely effected by the branched tentacles round the mouth, which are connected with the water-vascular ring. The network of vessels on the walls of the digestive tube seems to take part in the same work, water entering the intestine from the cloacal pouch, which is capable of expansion and contraction. Connected with it in some Holothurians are two branched tubular organs, the "respiratory trees" or lungs, through which water can pass into the body-cavity by fine pores at the ends of the branches. The left lung may be in close relation with the vessels of the dorsal intestinal plexus.

The Holothurians may attain a considerable relative size, some of them being a foot long, and capable of extending to thrice that length. Locomotion is largely effected by the extension and contraction of their bodies, which are continually changing their form by the action of strong muscles, both longitudinal and transverse. Sometimes, indeed, the contractions are so forcible that the creature throws out all its viscera through the cloaca, and lives for a time without them, until it can make good the loss by growing a new set.

The English Holothurians live among seaweeds or in sand or mud, with the body concealed and the tentacles exposed. They take a great deal of sand into their digestive tube, and the intestines of those which live in the neighbourhood of coral reefs generally contain fragments of coral. When the nutritious matter has been extracted from the coral or sand, the latter is passed out through the cloaca.

The Trepangs of the tropical seas form an important article of food in China. About thirty-five different varieties are enumerated by the Chinese traders, but only about five have any great commercial value. In Fiji they are accounted "royal fish," and used only to be caught by command of the supreme chief. Enough "fish" to fill a three-bushel bag, when dried, may be caught in two nights. The value of such a bagful would be from twenty-five to forty shillings, according to variety and the perfection with which it is cured. The process is effected as follows:—The viscera are

* Latin, *cucumis*, a cucumber.

† Greek, *synaptos*, joined together.

removed, and the "slugs" boiled for from ten to twenty minutes. After being well soaked in fresh water, they are arranged on frames in the curing-house. Here they are smoked and dried by means of fires, for which trenches are dug beneath the frames. Four days are required for this curing, after which the Trepang must be kept very dry, for it is remarkably hygrometric, and one damp slug will spoil a whole bag. The final product is an uninviting, dirty-looking substance, which is minced down by the Chinese into a sort of thick soup, a favourite dish among many of the European residents in China and the Philippine Islands.

(5) *Crinoidea*. The Crinoids differ altogether from the other Echinoderms in their mode of life. Instead of crawling about mouth downwards by the aid of tube-feet, a Crinoid remains more or less permanently fixed in one spot, either lying on its back, or growing on a stalk with its mouth upwards. The Stalked Crinoids or Sea-lilies (Fig. 18) are great rarities at the present day, though they were excessively abundant in the seas of some former geological periods, their fossil remains being known as Encrinites or Stone-lilies. Their structure, however, is fundamentally similar to that of the Feather-stars (Fig. 19), which we will now proceed to examine.

As in the Echinoderms generally, there are five rays, which correspond to the five ambulacra in the test of an Urchin (Fig. 14, A). But each of these five rays may fork from one to seven times, so that the number of arms may fall very little short of two hundred. In those of English seas, however, such as the Rosy Feather-star (Fig. 19), there are rarely more than ten arms. These arms are supported by an internal skeleton of limestone joints placed end to end, and are closely fringed with smaller jointed appendages—the pinnules*—which spring from them like the barbs from the quill of a feather. This feature sufficiently accounts both for the scientific and for the popular names (*Comatula*, Feather-star) of these animals.

Attached to the middle of the back of the Feather-star are a number of little clawed hooks, the cirri (Fig. 20, *ci*), by which the creature can anchor itself to stones and seaweeds. It detaches itself occasionally, and swims about for a while with a peculiarly graceful alternating movement of its arms, eventually settling down in its previous position, with its arms more or less completely extended. On the upper surface of each arm and pinnule is a groove (Figs. 20, 21, *ag*), which corresponds to the ambulacral groove on the under side of a Starfish arm (Fig. 9, *ag*). It is lined with cilia, which are in a state of continual vibratory movement, so as to produce currents in the water, that carry tiny food particles towards the mouth, where the grooves of all the arms meet (Fig. 19). The mouth may be either almost in the centre of the body or altogether excentric (Fig. 20, *m*), as in some Urchins. The whole of the coiled digestive tube is lodged within the body (Fig. 20, *c*), no part of it extending into the arms. It terminates in a tubular projection—the anal tube, the position of which depends upon that of the mouth (Fig. 19; Fig. 20, *at*).

The body itself consists of two parts: viz., (1) the cup or calyx formed by the skeleton, and (2) the visceral mass or disc, which is supported within this cup. The bottom of the cup is formed by a more or less saucer-shaped piece, the centrodorsal (Fig. 20, *cd*). Soldered on to this in most Feather-stars are the five first radials (R_1), which correspond to the ocular plates of the Echinoidea. The genital plates of this group are represented by the basal plates of the Crinoid larva (Fig. 8, *a, b*), which in most Feather-stars



Fig. 18.—STALKED CRINOID OR SEA-LILY (*Pentacrinus wyville-thomsoni*). NATURAL SIZE. (After Wyville Thomson.)

* Latin, diminutive of *penna*, a feather.

gradually disappear from the exterior of the calyx; though in one rare genus and in most Stalked Crinoids they are visible beneath the radials, alternating with them in position, and cutting them off more or less completely from the top stem-joint.

Jointed on to the first radials, and attached to them by muscles, are the five second radials

(Fig. 22, r_2), each in its turn bearing a third or axillary radial (r_3). The outer face of this is roof-shaped, and bears the lowest joints (B) of two arms, which may or may not fork again.

Immediately beneath the ciliated ambulacral or food-groove of each arm and pinnule lies a nervous band (Fig. 21, n), and deeper still, a blood-vessel (b), just as in the groove on the under-side of a Starfish arm (Fig. 9, n , b). Beneath the blood-vessel is the water-vessel (Fig. 21, w), which gives off side branches to the tentacles (t). These are delicate tubular organs, which are situated at the sides of the food-groove, and correspond to the tube-feet of the Starfish (Fig. 9, t). Not being required for locomotion, they are essentially breathing organs.

The water-vessels of the arms unite into five trunks which communicate, like those of the Starfish arms, with a ring-shaped vessel (Fig. 20, wr), situated in the lip around the mouth. There is, however, no such direct communi-

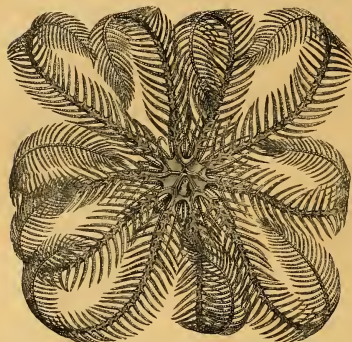


Fig. 19.—ROSY FEATHER-STAR (*Comatulid roseacea*), VIEWED FROM ABOVE. NATURAL SIZE.

The food grooves of the arms are seen converging towards the nearly central mouth, immediately below which is the projecting anal tube.

tion between this vessel and the external water as is effected by the stone-canal or water-tube of the Echinozoa. But water is able to enter the body-cavity by innumerable small tubular openings in its walls, the water-pores (Fig. 20, $w p$). These are lined by cilia, all working inwards; and, on the other hand, the water-vascular ring is in free communication with the body-cavity by means of delicate ciliated tubuli—the water-tubes (Fig. 20, $w t$), the open ends of which hang down into it, and thus establish an indirect communication between the body-cavity and the exterior.

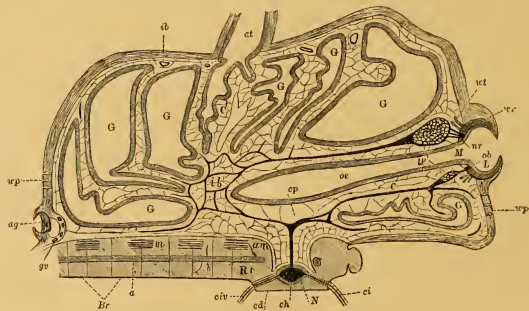


Fig. 20.—LONGITUDINAL SECTION THROUGH THE BODY OF AN IRREGULAR FEATHER-STAR (*Comatulid parvicirra*). MAGNIFIED EIGHT TIMES.

a, axial cords of the rays; oe, gullet; ag, ambulacral groove; am, branch of axial cord to muscle; at, anal tube; Br, arm-joints; C, body-cavity, chiefly occupied by connective tissue; cd, centro-dorsal; ch, chambered organ; ci, cilia; civ, cirrus; cv, central vessel; G, digestive tube; gv, genital vessel; b, blood-vascular network over digestive tube; L, lip; lp, labial plexus; M, mouth; m, muscle; N, fibrillar envelope of the chambered organ; or, oral blood-vascular ring; R, first radial; sp, water-pore; wr, water-vascular ring; wt, water-tube.

Between the dorsal skeleton of the arms and pinnules (Fig. 21, $p j$) and the water-

vessels, on their upper or ventral side, are three tubular prolongations of the body-cavity. The middle one of these contains the branched generative gland (Fig. 21, *ov*); while a current of water due to ciliary action proceeds outwards along the arms by the upper canal, and returns to the disc by the lower one.

The blood-vascular system of a Crinoid is considerably more complicated than that of the *Echinozoa*, owing to the presence of organs that are altogether unrepresented in that group, and are connected with the development of the stalk which all Crinoids possess for a longer or shorter period of their life. Situated more or less exactly in the vertical axis of the disc is a lobulated organ, the central plexus (Fig. 20, *cp*). This corresponds to the similarly named organ in the *Echinozoa* (Fig. 10, *cp*), and consists of a bundle of blood-vessels. Some of these terminate above in the oral blood-vascular ring (Fig. 20, *ob*), first traversing an extensive network (Fig. 20, *lv*) which is situated in the lip immediately below. Others extend outwards beneath the food-grooves of the disc (Fig. 20, *ag*) into the rays and arms, and surround the genital glands (Fig. 21, *gv*). Others, again, give off side branches, which form a network over the digestive tube (Fig. 20, *ib*). Towards the bottom of the disc the vessels of the central plexus, instead of joining into an aboral ring, group themselves into an inner set surrounded by five outer ones, which correspond in position with the radials. They pass downwards through the central funnel between the inner ends of the first radials, at the bottom of which the five outer vessels expand into five large chambers, which are regularly arranged around the central vascular axis. The structure thus formed, which is known as the "chambered organ" (Fig. 20, *ch*), is lodged within the cavity of the centrodorsal piece (*cd*). It is enclosed in a fibrillar envelope, processes of which extend outwards through all the joints of the rays and arms (Figs. 20, 21, *a*), and also into the cirri (*ci*), or clawed hooks borne upon the centrodorsal. These extensions into the cirri lodge minute blood-vessels (Fig. 20, *civ*), which are continuous either with one of the chambers of the chambered organ or with one of the vessels in its central axis. In the Stalked Crinoids the chambered organ is contained within the calyx, and the chambers are continued down the central canal of the stem, as five vessels enclosing a core of smaller ones. When the stem bears whorls of cirri, as in *Pentacrinus* (Fig. 18), the five outer vessels expand slightly in each cirrus-bearing joint, and each gives off one cirrus-vessel, the whole forming a small edition of the chambered organ in the calyx above.

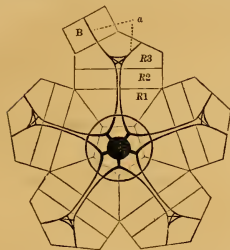


Fig. 22.—DIAGRAM SHOWING THE COURSE OF THE AXIAL CORDS PROCEEDING FROM THE CHAMBERED ORGAN WITHIN THE CALYX OF A FEATHER-STAR. (After H. Ludwig.)

a, axial cord; *B*, first arm-joint; *R1, R2, R3*, first, second, and third radials.

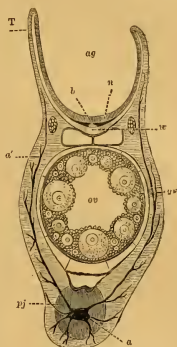


Fig. 21.—CROSS-SECTION OF A PINNULE OF THE ARCTIC FEATHER-STAR (*Comatula eschrichtii*), MAGNIFIED SEVENTY-FIVE TIMES. (Slightly altered from H. Ludwig.)

a, axial cord; *a'*, its branches; *ag*, ambulacral or food groove; *b*, radial blood-vessel; *gv*, genital vessel; *n*, radial nerve; *ov*, ovary; *p*, pinnule joint; *w*, water-vessels; *T*, tentacles.

The course of the extensions into the rays and arms of the fibrillar envelope of the chambered organ, which are known as the axial cords, is seen in Fig. 22. It is very difficult to determine whether they enclose blood-vessels, as the axial cords of the cirri do, but they are of extreme importance in another way. For all the movements of the arms and pinnules depend upon the integrity of their axial cords, and upon the connection of these cords with the central fibrillar envelope of the chambered organ. Some of the extensive branches (Fig. 21, *a'*) which are given off from the axial cords within every joint of the skeleton are distributed to the muscles connecting the successive joints (Fig. 20, *am*).

The nervous apparatus beneath the food-grooves (Fig. 21, *n*) is not connected with the muscles, and has no influence whatever upon the movements of the skeleton, which will continue to swim

about after the visceral mass has fallen out of the calyx, carrying with it the oral nerve-ring (Fig. 20, *nr*). We are led to conclude, therefore, that besides the additional elements in their blood-vascular system, the Crinoids also possess a complicated system of motor-nerves, which is altogether unrepresented in the *Echinozoa*.

The food of the Crinoids is mostly microscopic in character, such as Foraminifera, Infusoria, Entomostraca, and the larvae of the higher Crustacea. They are very gregarious, as are most of the Echinoderms, the Stalked Crinoids living in great forests on certain parts of the sea-bottom, just as they did in previous geological periods.

During a recent exploration of the Caribbean Sea by the United States Coast Survey, no less than one hundred and twenty-four specimens of Pentacrinini were obtained at a single haul of the dredge and its appendages. These must have swept over actual forests of the Sea-lilies, crowded together just as they must have lived in the old Liassic seas. Both in England (as at Lyme Regis) and abroad large slabs of shaly limestone are found containing collections of fossil Pentacrinites, some of them very perfect and remarkable for the great length of their stems. The total length of the stem of one specimen found in Germany, as measured by its broken pieces, was found to be seventy feet, while others with stems fifty feet long are not uncommon. They must have presented a curious sight in their native seas, each with its long stem on which was the crown of arms, not more than two feet across when fully expanded.

The Crinoids of the Paleozoic period differ very considerably from those preserved in the Secondary and Tertiary rocks. In many of them the mouth was not on the external surface of the body, for it was covered in by a dome of rigid heavy plates. But there were food-grooves on the arms, just as in the recent Sea-lilies and Feather-stars, and at the circumference of the dome were a number of openings, one for each groove, through which the food particles passed on their way towards the mouth.

The earliest representative of the more modern type of Crinoid in which the mouth is open to the exterior is the "Lily Encrinite," from the Trias of Germany, a very elegant and well-known species. In an old German book about the natural history of Altenburg, dated 1774, it is recorded that the Emperor of Germany once offered a hundred thalers for a good specimen of this Stone-lily attached to its stem, and free from the matrix in which it had been embedded.

Little need be said about the *Cystoidea* and the *Blastoidea*, two groups which are of the highest zoological interest, owing to their furnishing numerous connecting links between the Crinoids and the Echinozoa. They have been extinct since the close of the Paleozoic epoch. They were stalked Echinoderms, like the Crinoids, with food-grooves converging towards a central or excentric mouth, and were provided with respiratory organs, much resembling the interradial pouches of the Ophiurids in their general structure, while it is very doubtful whether their water-vascular system was provided with tentacles. As in the Crinoids, the body-walls were supported by limestone plates, which were arranged very regularly in the Blastoids, but somewhat less so in the Cystids.

Further information upon the subject of the Echinoderms will be found in the works of Agassiz, W. B. Carpenter, Duncan, E. Forbes, H. Ludwig, Lütken, Lyman, Metschnikoff, J. Müller, Sars, Selenka, Semper, Sladen, Wyville Thomson, and others.

P. HERBERT CARPENTER.

THE GROUP ZOOPHYTA.

CHAPTER I.

THE HYDROZOA, OR HYDROMEDUSÆ.

The Group **ZOOPHYTA**—Class **HYDROZOA**, OR **HYDROMEDUSÆ**—Characters—Colonies—Reproduction—Order **CTENOPHORA**—Characters—Venus' Girdle—Order **DISCOPHORA**, **MEDUSÆ**, OR **JELLY-FISHES**—Appearance—The Disc—Method of Reproduction—The *Lucernaria*—Order **SIPHONOPHORA**—Characters—The "Portuguese Man-of-War"—The *Calyculophore*—The *Physophore*—The *Tedella*—Order **HYDROIDA**—Genus *Hydra*—Characters—Gemination—Power of Reparation—Sub-order **TUBULARIA**—*Perigoniinus*—Characters—Other Tubularians—Sub-order **CAMPANULARIA**—Sertulariidae—Plumbariidae—Sub-order **TRACHOMEDUSÆ**—Order **HYDROCORALLINA**—Milleporidae—Description—Characters—Stylasters—Other Hydrocorallinae—Classification of the Hydrozoa.

THE Jelly-fish, the Sertularian Polypes, the Hydra, the Sea Anemones, the Alcyonarians, and the Stony Corals are well-known forms of animal life, and their distinctness from the Echinodermata and the other groups already noticed is evident. They constitute the group Zoophyta, and have more or less of a radiate structure, with tentacles; and there is a digestive cavity within their body, with wide or canal-shaped offshoots from it. The hollow space within the body thus occupied has given them another name—*Cœlenterata*;^{*} but before this term was applied, the plant-like appearance of many of the group had entitled them to the term Zoophyta.[†] They are distinct from the group Spongida (Sponges), although some synthetic-minded morphologists classify all together as *Cœlenterates*. Formerly the name of Polypes, or Polypifera, was given, on account of the tentaculate body. There are two classes of the Zoophyta—the Hydrozoa and the Anthozoa.

THE CLASS HYDROZOA, OR HYDROMEDUSÆ.

A vast number of marine and a few fresh-water animals, popularly called Polypes and Jelly-fish, belong to this class. All are very delicately and beautifully constructed, and they present great varieties of shape and methods of life. The fresh-water Hydra, the pretty feathery Polype-stems on sea-shells and rocks, the Sertularians and Tubularians, the Jelly-fish, the Portuguese Man-of-war, the Beroës, the Stony Millepores of reefs, and the coloured Stylasters of the deep sea, all have certain structures in common, in spite of their diverse shapes and habits.

The essential parts of these animals are a mouth, leading directly to a cavity which is digestive in its function, and relates to the circulation of a nutritive fluid, an outer delicate skin, or ecto-derm, encasing the body, and an inner, lining the internal cavity and mouth, and the reproductive organs which are outside the stomachal cavity, and are usually in specially modified parts of the body. These last may be simple sac-like projections of the ecto-derm, or they may be complicated, and have an inner, and also a meso-derm (middle-skin), covered by the ecto-derm, and may resemble ball-shaped Jelly-fish stuck on by their upper part.

The Hydrozoa have tentacles, some very slender and others comparatively stout, and certain stinging cells called nematocysts. The organs of special sense are in a very rudimentary condition, but the tissues as a rule are highly sensitive to irritation, and are very contractile. Some of the class are free-swimmers, and others are fixed during all or part of their life cycle. Most are soft and easily destroyed, but some have very solid sub-structures.

The stationary forms are in colonies of individuals, connected by root-like supports, and in some of the free-swimming kinds there is a colony beneath a float—as in the Portuguese Man-of-war—but the Jelly-fish are solitary. The colonies may be of simple or of branching individuals, some of which are for the purposes of the nutrition and others for the reproduction of the species. In their construction there is an outer and inner derm, and a central cavity reaching from the root-like supports to the mouth. The opening from the outside into the mouth is without a gullet, and the stomach, or somatic cavity, is digestive as well as referable to the circulation, and it may be simple or may be continuous with canals which radiate from it. The reproductive process is very varied. In some free-swimming Jelly-fish the kind is reproduced by the budding of small ones from the region of the mouth, or eggs may be developed and set free, which become like the parents. But these methods

^{*} Greek, *koilos*, hollow; *enteron*, bowel.

[†] Greek; *zoon*, animal; *phyton*, plant.

are rather exceptional, for the greater part of the free-swimming Medusæ, or Jelly-fish, are the highest developments of individuals which began life in a different shape, and had different habits. The fixed and polype-looking kinds, which have a branched stem, and on it one kind of zooid for nutrition and another for reproduction, develop in certain receptacles of this last, either as larvæ, which escape as ciliated elongate or globular bodies that settle down and become like their parent, or else as plano-blasts—wandering buds—Jelly-fish or Medusæ—which, when they escape, grow and develop sexual elements, and their eggs hatch into the shape of the young individuals of the fixed colony. The generation is then said to be alternate. It is probable, however, that the rudiments of the contents of the generative sacs are developed within the central canal of the body, and pass thence into special organs, and grow into shape. Budding also occurs, and similar forms are reproduced by it. Usually there is great transparency of the tissues, and cilia exist on some kinds, and all have sting- or nettle-cells, or nematocysts in their derm. These are cells with a spiny thread coiled up in them, which escapes on pressure or irritation. The touch of the fine thread, with or without the contents of the cell-sac, produces a paralysing influence on minute crustacea and animalcules, which form the bulk of their food.

The contrast in the dimensions of the Hydrozoa is remarkable; some of the Jelly-fish are several feet in diameter, and others are like little balls, and the branching or fixed kinds may be microscopic or some inches in length; the first are muscular in some parts, and the last are more or less chitinous in their investment. Special senses are represented in the free forms by eye-spots and minute particles of mineral matter or lithocysts, and in most the tentacles which surround the region of the mouth or the margin of the disc of the Medusæ are retractile, and are weapons of offence or of capture. The nervous system is very rudimentary, being more or less in connection with the muscular fibres, in some being made up of nervo-muscular tissues, contractile and sensitive, in the meso-derm, or middle-skin. Haeckel has described a circular band of nerve, on the inner side of the circular canal of the ball-shaped Medusæ, and states that it gives off shoots to the lithocysts, radial canals, cavity, and mouth. But the evidence is not very satisfactory. There is no circulatory system, properly speaking, and no special blood; and the juices of the body are aerated through the delicate tissues. All are aquatic. The Hydrozoa are divided into five orders—the Ctenophora, Discophora, Siphonophora, Hydroida, and Hydrocorallina.

ORDER CTENOPHORA.

These are free-swimming Hydrozoa, usually globular or cylindrical in shape, and rarely ribbon-shaped, and they are more or less lobed. They have rows of flappers placed like lines of longitude on their body, and sometimes two tactile filaments, which can be retracted. The stomach is more or less tubular, and is associated with a series of canals. Never budding, they do not produce colonies or compound organisms, and they are characterised by the great development of the middle tissue, or meso-derm. A nervous ganglion, at the side remote from the mouth, with eight radiating cords to the paddles, appears to have been made out satisfactorily.



BERGÈ PILEUS.

The Ctenophore,* not having a disc, and not resembling the Medusæ, or Jelly-fish, in their shape, have a totally different method of moving in the water. Whilst the great Jelly-fish contract and expand their bodies in regular succession, moving in a very stately manner, the Ctenophore dart here and there, rapidly ascend, descend, and move slowly at will; so that at night, when the great Medusæ are phosphorescent, and look like pale, slowly-moving spheres under water, the little Ctenophore flash here and there with a bright light, and are soon out of sight. They move by the rapid flapping of countless little paddle-like processes arranged in vertical rows along the surface of the body, like the teeth of a comb. The rows may all be in full vigour of movement, or one only may act; and, indeed, separate paddles appear to move independently and at will. The little creatures thus rise and move obliquely, or fall and progress, according to the quantity and the position of the skin machinery which may be used. They can stop and float in mid-water, and again dart off; and A. Agassiz

* Comb-bearers.

noticed that sometimes one-half of their flappers were acting, whilst those of the other side of the body were at rest, thus producing rotary motion.

The combs, which are very small, are placed on horizontal bands of muscular tissue, and when they move by day they are iridescent and very beautiful.

One of the most beautiful of the Ctenophoræ belonging to the globular sub-order is the type of the family Cydippidæ, and is a species of *Pleurobrachia*.* It is a small transparent sphere, occasionally becoming bulged out, and there is a slit-like mouth on the top, and a dark eye-spot is at the other pole. Eight rows of fringes run, like lines of longitude, from pole to pole, dividing the surface, like the ribs on a melon. Hanging from either side of the body, from just above the eye-speck, are two very long tentacles, like soft fringes of feathers on a spring. They are in rapid movement when necessary, coiling, undulating, and moving the little body in most graceful curves, or they may stream out listlessly, and float behind, a foot or eighteen inches in length. In an instant they may contract, and fold into a knot not larger than a pin's head. The prevailing tint of the little sphere is given by the motions of these wonderful fringes, and it may be yellowish, pink, green, red, and purple. These arise from small sacs, into which they may be withdrawn. The mouth is brought constantly within reach of its minute prey—small immature marine animals and plants—by the motion of the fringes, and the food passes down a wide digestive cavity between two tubes. These unite at the lower part of the body in a single funnel-shaped cavity, which is a reservoir for the circulating fluid poured through an opening in the digestive cavity into it. The food and much water pass into this canal and are sent ramifying through a series of tubes about the body. These chymiferous tubes start horizontally and at right angles to the digestive cavity, from the point of junction of the vertical tubes and the canal.

When they reach the periphery, each one joins a longitudinal tube which is just within one of the rows of flappers, and more or less connected with it. The Atlantic, and the northern parts especially, are favourite localities of this genus, but others of the family are found in the Mediterranean and the Pacific Ocean.

The pretty *Beroë* and the genus *Rangia* belong to the sub-order Eurystoma, and their oval bodies are contractile, and without lobes and tentacular filaments of much length. The mouth and stomach are large.

Some of the Ctenophoræ, such as the *Bolinæ*, are lobed in the region of the mouth, which is downwards, and the body departs from the globular shape and does not have long tentacles. They move with a sluggish, slow, and undulating movement, and have the eight rows of small paddles, but they differ in length according to their position on the body. The motion is assisted by appendages, called auricles of the lobes; and the whole animal, according to Agassiz, resembles a white flower with the crown expanded, and especially when it reverses itself and floats mouth upwards. The genus is found in the Northern Seas.

The family Cestidæ belongs to the ribbon-shaped order; and *Cestum veneris* (Venus' Girdle) of the



VENUS' GIRDLE (*Cestum veneris*).

* *Pleurobrachia rhododactyla*.

Mediterranean, is a long, slender, narrow, strongly-compressed, very agile creature, rather enlarged in front and behind. There are two tactile filaments, each one with an offshoot, and they are fixed to the buccal or mouth region, which is carried downwards. It is covered with moving cilia, and four ranges of motile organs, and four vessels are noticed on the upper part of the body. Four other vessels are in the lower part, and they are in communication. The graceful undulating movements of this Cestum have always excited the admiration of those naturalists who have had the good fortune to see them.

Some of the Ctenophoræ are very abundant, and hundreds of the group, characterised by having a bell-shaped body, and belonging to the Eurystomæ, are caught in the Northern seas when fishing-nets are brought up. The common Beroë of the British coasts is one of them, and so is the Rosy Idya of the American Seas.

All the Ctenophoræ are produced from eggs, and the young swim in the egg long before they are set free; they have the flappers of great size in relation to the rest of the body. An examination of the development of the young of the different great groups proves that certain structures, which last on in the less complicated forms, are transient in the higher ones.

ORDER DISCOPHORA.—THE MEDUSÆ, OR JELLY-FISH.

Everybody is familiar with the appearance of the large Jelly-fish which move so gracefully by expanding and contracting their umbrella-shaped discs, and on the surface of which four more or less circular coloured patches are to be seen. Hundreds occur off the British shores, swimming with the tide, and rising and sinking in the clear sea in the summer. They are semi-transparent and almost colourless when seen by daylight, and some of them are luminous at night. When one is caught by the hand, unless care be taken, the fingers enter its tender substance, and it falls motionless into the water. And when one is found stranded and dead on the sand, the edge of the disc is seen to be lobed and furnished with a fringe of thread-like tentacles; the circular spots on the top are also visible, and so are numerous markings, like lines, eight often being principal, passing from the top of the disc to its circumference, and uniting in a canal which passes all round the edge, just within the substance of the Jelly-fish.

On turning this Discophora or Medusa on its back, and looking at the under surface of the disc, a central opening is to be found, into which the finger can pass. This is the mouth, and the passage leads through the substance of the disc to a cavity, the stomach, which is surrounded by the four coloured circular spots.

The substance of the disc has an outer very delicate skin covered with cilia, and on the under surface of the disc muscular fibres stretch from the margin to the edge of the mouth. In some very large kinds* the substance itself is rather tough; and yet Agassiz states that one which weighed 34 lbs. being left to dry in the sun for some days lost $\frac{90}{100}$ ths of its original weight. Such an one would be seven feet in diameter without its tentacles; but from one to five feet are the common sizes. Hence these great discs principally consist of water, and it is held in the meshes of a connective tissue, which contains cells possessing amoeboid movements. The skin which lines the mouth and the stomach also enters the four circular cavities, and also the canals which radiate from the stomach in the disc substance, and reach the circular canal.

At the bottom of each of the notches on the edge of the disc which separate it into lobes is a small oval body containing calcareous matter on a minute stalk, the cavity of which is continuous with one of the radiating canals just noticed. Pigment may also exist about the little body, which has been called a lithocyst, and has been deemed an organ of special sense for hearing or seeing, or both. A membranous covering usually protects the so-called eyes.

The entrance to the mouth is in the midst of a part of the body which is denser than the rest, and, indeed, the disc may be considered to be an appendage. It is made up of four parts, which may be divided so as to present eight radiating arms, in the midst of which is the passage to the stomach. This part, which hangs down, when the disc is in motion, is called the hydranth. The circular spots are reproductive organs, and the eggs escape from them into the stomach, and pass forth through the mouth. In some kinds the stomach has pouches, and in all, the radial canals whether

* *Cyanca arctica*.



JELLY-FISHES.

simple or ramified, carry the digested food to the circular canal. No special organs of circulation exist, and respiration is effected by the membranes or skin of the disc.

The fringe of tentacles around the disc may be very short and sparsely developed, or these appendages may be many feet in length and very numerous. They are supplied with nematocysts, which are the stinging organs, and which are sufficiently annoying to some thin-skinned bathers.

The nervous system may exist in relation to the eye-spots, and in a very rudimentary condition elsewhere. Small swimming Invertebrata are the food of the Medusa.

The methods of reproduction and development are very remarkable, and the dimensions of the

full-grown disc are greatly in excess of those of the first stage of life. One great group of the Discophoræ, including the common Jelly-fish of the British seas, lay eggs in the autumn when they are swimming near to the coasts and estuaries. The parent dies, and the young escape from the eggs as little spherical bodies, covered with cilia. Each one attaches itself by its base to a rock or seaweed, and tentacles are formed at the other end, the body gradually becoming elongate. With growth some contractions occur around the young form, the first being just below the circle of tentacles. Tentacles soon appear on the edges of the contraction nearest the base, and the edges of the other contractions simply become lobed.



AURELIA AURITA.

After a while these contractions become deep, and the animal resembles a set of plates placed one over the other, the top and bottom ones having 'circlets' of tentacles. At a certain period, when the whole is less than an inch in height, the entire structure breaks up; the top falls off and dies, and the bottom part remains fixed, whilst the rest separates into as many discs as there were contractions, and each swims off to become a gigantic Discophora.* This process is a good example of the alternation of generation, and the young and tentacled form is the nurse or intermediate stage. It has been called "Hydra-tuba," and in the next stage it is called Strobila.

STROBILA OF AURELIA
FLAVIDULA.
(After L. Agassiz.)

The Discophoræ include the great free-swimming oceanic Medusæ, but it is not clearly proved that all do pass through the peculiar stages of development. Some may have a very different early life, and may belong to other groups of the Hydrozoa. Two sub-orders are distinguished. The Pelagida, containing such genera as Cyanea, Aurelia, and Pelagia, have a large central mouth surrounded with four arms, often subdivided, and fixed on to a buccal peduncle. The fringes of tentacles on the lobed margin of the disc may be long or short. The genital organs are four. The Rhizostoma have a great development of the structures surrounding the mouth, which gives the name from their root-like appearance. The mouth, with growth, closes at its lips, and passages into the digestive tract are formed down the rootlets, at the ends of which are small openings, like little suckers. There are no marginal filaments.

* Example, *Aurelia flavidula*.

One of the prettiest free-swimming Medusoids is more or less bell-shaped, but it has a stalk-like top, by which it can attach itself to weed or rock, and the margin of the bell is separated into eight knobs, or lobes, covered with tentacles. The membrane of the bell is festooned between the lobes, and the whole animal is very transparent. These *Lucernariæ* are very contractile, and can change their shape, and their movements are most varied. They swim by contractions and expansions of the disc, like ordinary Jelly-fish; but when they settle down, the lower part of the disc curves up and the



REPRODUCTION OF DISCOPHORA.

body is fixed on its peduncle. L. Agassiz, in his charming book on the marine animals of Massachusetts Bay, writes:—"It frequently secures itself in the upright position, spreading itself in the form of a perfectly symmetrical cup or vase, the margin of which is indented by a succession of inverted scallops, the point of junction between two scallops being crowned by a tuft of tentacles. But watch it for a while, and the sides of the vase turn backward, spreading completely open, till they present the whole inner surface, with the edges even curved a little downward, drooping slightly, and the proboscis rising in the

centre. In such an attitude one may trace, with care, the shape of the mouth, the lobes surrounding it, as well as the tubes and cavities radiating from it towards the margin. A touch is, however, sufficient to make it close upon itself, shrinking together, or even drawing its tentacles in and contracting all its parts, till it looks like a little ball hanging on the stem. These are but few of its manifold changes, for it may be seen in every phase of contraction and expansion."

The bell is not a hollow hemisphere, but is a mass of gelatinous hardness, and the peduncle is an extension of the bell, and it has a minute disc at the end, for attachment. The mouth is in the midst of the bell, which has an inverted look, is square, and is on a projecting proboscis. The body-cavity is four-chambered, and each communicates with the mouth. Triangular-looking structures pass outwards to the tentacular knobs, and are the ovaries, consisting of a number of little bags, each crowded with eggs. These drop into the stomach, and are passed out of the mouth. The tentacles are club-shaped, and they have an orifice which leads through a canal to the chambers of the digestive cavity, two of the clusters being connected with each chamber.

"Their chief office," writes L. Agassiz, "is to catch food and convey it to the mouth; but the *Lucernaria* frequently uses them in locomotion, fixing itself by them, and loosing the end of its peduncle." Between the clusters are slight projections, which are short and compact, and they are used as claspers to a certain extent. They contain a slight pigment spot, which may be an eye. The colour of the American form (*Lucernaria auricula*) is greenish, with a faint tinge of red, and it assumes a beautiful aquamarine tint. The British species thrive in aquaria, and are very beautiful objects.

LUCERNARIE ON PIECE OF SEAWEED (*Lucernaria octoradiata*).

ORDER SIPHONOPHORA.*

These are free-swimming Hydrozoa, but each one consists of a colony or assemblage of individuals united in a common stock, termed a hydrosoma,† and placed under a more or less tough part, which acts as a float. This last may be large and crested, or it may be small, and united to others which fulfil the same office. An air-sac, from which air can be expelled, enters into the composition of the float.

Nutritive and generative individuals, or zooids, exist in the colony, and long pendant tentacles add to the beauty of the forms. In some an oil bubble, surrounded by tissue, acts as a float. They reproduce by developing buds, which give forth planoblasts (wandering buds) or medusæ. These develop eggs, which grow into the shape of the float and colony.

The "Portuguese Man-of-War"‡ may be seen in the tropics sailing on the surface of the sea, its

* Tube, or siphon-bearers.

† See Note on p. 286.

‡ *Physalia utriculus*.

coloured float, with a crest to it, being partly above water, and a multitude of tentacles, some long and others short, trail behind in the waves.

The float is sac-like, long, pointed at one end and rounded at the other, and there is a small opening at either end surrounded by muscular fibres. When the float is held in the hand, it feels light, and a little pressure forces air out of it. The sac contains an enlargement of the digestive cavity, and also a long air-sac, divided by muscular partitions, which do not, however, communicate with the digestive cavity, but open externally. Beneath the float are numerous long tentacles without lateral branches, and with kidney-shaped enlargements here and there, armed with nematocysts. Besides these, there are a host of shorter structures, forming, really, a hydroid colony. There are tentaculate individuals, or zooids, called trophosomes, in groups which deal with the nutrition, and bunches of other individuals, or gonophores, with medusa-like buds, and which are reproductive. These escape, and the Physalia is their product.

Physaliæ are found in vast multitudes, and about 120 species exist, and they are amongst the most graceful and beautiful objects of the ocean and large seas.

The sub-order Calycophoræ have the hydrosoma, or swimming body, propelled by special swimming bells, or nectocalyces, each of which resembles the bell of a medusa without the root-like processes. The cavity of the bell is muscular, and the pedicle of attachment has a process of the body-cavity branching into canals. The bells may be retracted into the mass of the body, which is flexible, unbranched, filiform, and walled.

Praya diphyes has two small rounded swimming sacs, nearly alike, and they are placed opposite and at the end of the body. They have groove-like processes for retraction, and the male and female individuals are attached to the same body-mass, or cenosarc. *Diphyes* is also a genus of the sub-order, and has two large natatory sacs, one placed, as it were, within the bell of the other.

Physophora hydrostatica, of the Mediterranean, belongs to another sub-order—the Physophoræ—and has a rather twisted floating body, whose natatory vesicles are in two rows. Below these is a crown of tentacles surmounting the colony of nutritive, generative, and filamentary zooids.



PHYSALIA UTRICULUS.

The little *Velella*, of the sub-order Discoida, has been compared to a little raft with an obliquely placed upright sail; the raft has its system of canals, and the thin membranous sail is the air-sac. It is cartilaginous, and the concentric tubes found within open externally. Below the disc are the nutritive and generative zooids, and there is usually a large polype in the midst of this crowded submarine colony. There are tentacles on the edge of the disc, which may be bright blue, purple, or brown in colour. It sails along with its upright membranous part, and is kept up by the air canals. The generative zooids produce medusæ, which become free. L. Agassiz describes the medusa of *Velella nutica* as a long bell, with a short proboscis in the upper part of the cavity, which is connected with the outside by a tubular opening. Eggs are the product of the medusæ, and they develop into *Velellæ*.



PRAYA DIPHYES.

ORDER HYDROIDA.

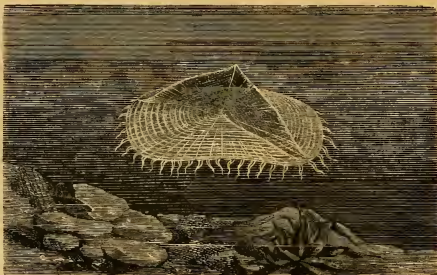
The fresh-water polype is a common name for several species of the genus *Hydra*, which are to be found in ponds and slow streams, hanging to the under surface of floating leaves and upon the stems of water plants. If in the summer time a glass jar is filled with clear pond water, and some of the duck-weed also, minute bodies, like

pieces of green sewing silk, about the sixth of an inch long and very slender, will be seen on the sides of the vessel, or on the weed, beneath the water. On using a low magnifying power, the little

object is seen to be fixed by a small sucker-like base, and to have a cylindrical body, terminating in a crown of feelers, or tentacles, six to ten in number, and shorter than the body (*Hydra viridis*).

It usually hangs downwards, and the tentacles stretch out, curve, expand, and contract, whilst the body elongates, and often, on a slight alarm, contracts, and becomes more or less globular in shape. A minute crustacean swims along close to the *Hydra*, and one of the tentacles touches it. The movement of the living prey is

arrested at once, the tentacle adheres to it, and then the whole crown of feelers comes to help, and the morsel is dragged to the mouth and slowly passes into the body. There, enclosed in the visceral cavity, the victim is slowly digested, and the undigested matter is, after a time, returned by the mouth. Tired of its position, the *Hydra* may be seen to bring its crown of tentacles



VELELLA LINBOSA.

close to the glass or weed by bending the body. It fixes itself by the tentacles, lets go the sucker end, and remains for a second or two, or more, head downwards. The original base moves forwards, the body bends, and applies it to the supporting substance, to which it becomes adherent before the tentacular extremity is set free. By this process of creeping some progress is made. But often the Hydra gets as close to the top of the water as it can, and suddenly casts its body loose and turns the base upwards, just beneath the surface. Waving the tentacles about, the process of swimming is carried out, and the expansible disc, by floating on the water, assists.

After a while a little nodule appears on the body of the well-nourished Hydra, and it grows outwards, and soon a crown of tentacles appears at the free end. This is a bud which resembles the parent. A second may grow, and thus the stem and buds constitute a little colony. But the buds drop off, and, having developed a base, become free, and take care of themselves. In some instances the Hydra diminishes in its girth at one spot, and at last breaks off there. The free portion develops a base, and the fixed part a crown of tentacles, and thus two individuals are formed by a process of fissiparity. In the autumn, eggs escape from the outer tissues, having been previously fertilised, and their central mass forms a clear ectoderm and a darker endoderm. This escapes from its cover, and is set free. No cilia are on it, and it gradually develops tentacles.

In the adults the outer tissue, or ectoderm, of the body is continued up unto the tentacles, and consists of large nucleated cells, from whose bases filaments are continued inwards. Surrounding these neuro-muscular cells are others which contain nematocysts. Moreover, minute points project from the surface cells.

The inner tissue, or endoderm, which lines the visceral cavity and the inside of the tentacles, contains cells, with amoeboid movement, and spaces in the midst called vacuoles. Some have long cilia. The food passes down an opening in the midst of the bases of the tentacles, and reaches a sac-like stomach, and particles of it get into the vacuoles, and are digested there.

Vertical fibres and amoeboid cells exist between the layers of the body, or, rather, there is an inter-cellular substance common to both layers.

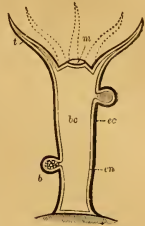
One of the most extraordinary gifts of the Hydra is its power of reparation of injuries, and reproduction of new individuals out of portions into which it has been accidentally or naturally divided. If a tentacle be cut off, an entire animal is formed out of it; if the body is cut in half, it will join together again if the parts are placed together, and if not, two individuals will result; if parts of one individual are placed on the cut surface of another, they will grow together; and if the body be turned inside out, the old ectoderm takes on the digestive power, and the former endoderm that of the skin.

Another common Hydra is the brown one (*Hydra fusca*), and its tentacles are longer than the body.

These interesting and readily obtainable creatures are species of a genus which belong to a family—the Hydridæ of the sub-order Tubularia, classified under the great division or order of the Hydroida. The Hydroida differ very considerably from the other orders already noticed, in one part or during the whole of their existence. They are very plant-like and stationary during the whole of their existence, and they sometimes develop buds which become free-swimming medusæ. These reproduce ova, which become

like the fixed or parent stock. The exceptions to this rule are few, and the characters of the Hydra are rather exceptional.

The fixed polypes of one of the sub-orders, the Trachomedusæ, are not known, and they may not have an alternation of generation; and all the medusæ of the plant-like or stationary forms have not been discovered. Moreover, different genera of the Hydroida may have medusæ, which present the closest similarity, and the medusæ alter much as they develop during growth. The polypes have



DIAGRAMMATIC SECTION OF HYDRA.

ec, ectoderm; en, endoderm; m, mouth; t, tentacles; bc, body cavity; b, bud.



NEMATOCYST OF HYDRA VIRIDIS.

a simple internal structure, and may or may not be provided with a mouth and a gastric cavity. This is simple and without œsophagus and divisions, and is ciliated, as a rule. Tubes may pass from it in some large forms. The nervous system is neuro-muscular in the fixed forms, and there is a rudimentary nervous structure in relation to the marginal canal and lithocysts of the medusæ. The sexes are separate, and the colonies contain male and female stock, besides those destined for alimentation.



A



B

A, *HYDRA VIRIDIS*, ATTACHED TO DUCKWEED; B, MAGNIFIED; WITH A BUD.

The Hydroids, therefore, consist of colonies of polypes, more or less dendroid or cespitose in shape, which produce sexual buds, which often bear free medusæ.

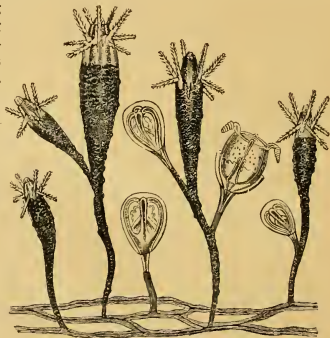
The order contains several sub-orders, such as the Hydrocorallinæ, the Trachomedusæ, the Tubulariæ, and the Campanulariæ, of which the last two are the more closely allied, and are very typical of the order.

SUB-ORDER TUBULARIA.

Dr. Allman found in the Firth of Forth, in the month of June, whelk-shells covered with a mossy-looking growth, which, on a slight magnifying power being applied, proved to be a number of polype-looking things, having their stems united at their bases by a set of roots, and having tentacles at the other end. Some of the stems were narrow where attached to the roots, and became smaller near their ends, which diminished in size, and resembled small cones. At the top of the cone is a small mouth, and just below it is a circle of six to ten tentacles, some projecting outwards, and others upwards and downwards. On the stem, but not reaching up as far as the tentacles, is a skin roughened with particles of sand, and a more delicate one extends to the mouth. Some of these stems had

an offshoot made like themselves. They were about two lines long. Very contractile on irritation, and having the power of killing prey with nematocysts, which occur in bundles on the tentacles, these stems receive food and digest it, and are the nourishing parts of the colony.

A second kind of stem exists, but it is very small where it joins the common root, and then it becomes suddenly globular, and has neither opening nor tentacles when small. This kind has nothing to do with nutrition, but is part of the reproductive apparatus. For in June the globular mass enlarges, and becomes transparent, and after a while it bursts, and a small Medusa or Jelly-fish, egg-shaped at first, but growing more ball-shaped, escapes. This has two long tentacles on the edge of its umbrella, and the mouth within has four shallow lips. It is a pale reddish little thing, and moves after the fashion of larger ones. Leading a free-swimming life, and taking in food, it produces eggs which, after hatching, settle down, and each one becomes in the year following a colony of the stems just noticed. Such an animal belongs to the Hydroids, and from having the generative bud and tentacles of the stem uncovered by any special hood, it is called one of the gymnoblast* group, or sub-order.



PERIGONIMUS VESTITUS. (After Allman.)

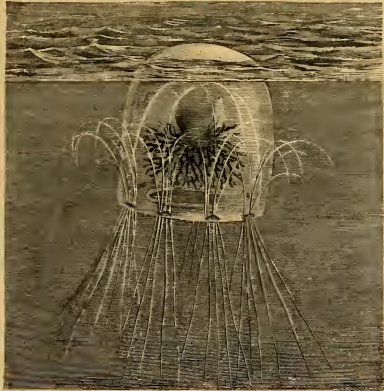
The species is *Perigonimus vestitus*, and the genus was named by Sars from the fact that sometimes the medusa buds are found around the nutritive stems (Greek, *peri*, around; *gonimos*, productive). It belongs to the family Eudendridæ, of the Gymnoblasteæ.†

* Greek, *gymnos*, naked; *Ustos*, bud.

† Certain terms are employed to describe the Hydroids, and if the description of the species of *Perigonimus* be referred to, the terminology becomes easy of comprehension. The entire colony, with all its parts, stems, and roots, is the Hydrosoma (Greek, *hydra*, a monster; *soma*, body). The stems which are nutritive only form the Trophosome (Greek, *trophê*, nourishment;

Eudendrium has a species forming pretty little tree-like shapes in rock pools near low water spring tides on the southern coasts of England. It* is about three-quarters of an inch in height, and consists of rootlets and a stem with regular branches, and has the nutritive and generative zooids on it. The outer tissue, or perisarc, is distinctly marked with rings, and is annulated, and there are about twenty tentacles, some looking upwards and others downwards. The gonosome has male and female sacs in whorls, and they are placed just behind the tentacles or on the stem lower down. Some small medusae of the genus *Lizzia* belong to this group.

A third genus is *Hydractinia*, and it is remarkable for its resemblance to *Millepora*, one of the *Hydrocorallinae*, but it is without the hard calcareous base of this last.



LIZZIA FLOATING BENEATH THE SURFACE.



EUDENDRIUM INSIGNE. (After Allman.)
A, colony, natural size; B, male colony, magnified; C, female bearing gonophores, magnified.

Hydractinia has several species, and it was at first taken to be a Bryozoon, from the horny spinous crust which it forms on the surface of empty univalve shells. It forms numerous colonies, and the hydranths are claviform, and arise from the surface of the common base, or hydrophyton. There is a crown of tentacles, which are filiform, and it encircles the conical mouth. The generative buds are on smaller polypes, which are without mouth, and end in globular clusters of thread cells representing the tentacles of the hydranth. The generative buds cluster around this polype, which is called a blastostyle, and some contain, around a central body, the ova, and others the male elements.

A common species (*Hydractinia echinata*) is found on the shores of England, France, and Belgium, and covering more or less dead univalve shells inhabited by Hermit crabs. It has, near the margin of the base, spiral appendages, cylindrical in shape, and very contractile and movable. They twist and untwist with great vivacity.

The genus *Podocoryne* is not very unlike the last mentioned, but all the polypes are tentaculate.

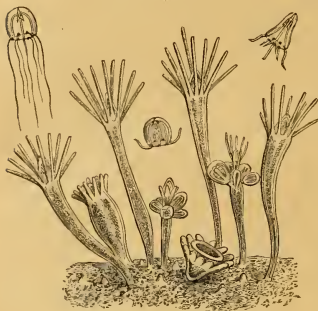
soma, body). The buds which produce the medusae, or the generative part of the colony, are the Gonosome (Greek, *gonos*, offspring). When the Trophosome branches, or has offshoots, each one is a zooid, and the proper nutritive zooid, which has a mouth and digestive cavity, is the hydranth (Greek, *hydra*, hydra; *anthos*, flower). The mouth is at the end of a cone, which is called the hypostome (Greek, *hypo*, under; *stoma*, mouth). The common basis of the Trophosome, by which the zooids are connected, is the hydrophyton (Greek, *phyton*, a plant), and the end of the hydrophyton, or root, is the hydro-rhiza (Greek, *rhiza*, a root). All the hydrophyton between the root and the hydranth is the hydrocaulus (Greek, *kaulos*, a stem). The bud, or zooid, which contains the reproductive elements, is a gonophore (Greek, *gonos*, offspring; *phoreo*, I bear).

A planoblast (Greek, *planos*, wandering) is a generative bud, fit for a free locomotive life; and a blastostyle (Greek, *stylos*, a column) is a columniform zooid, destined to give origin to generative buds. Umbrella is a term for the gelatinous bell of a medusa; the manubrium is the part carrying the mouth; and the velum (a veil) is a membranous perforated diaphragm, which stretches across the orifice of the umbrella which communicates with the external water.

* *Eudendrium insignae*.

The buds on the generative tentacle-bearing parts develop into medusæ, which are deep bell-shaped. Each has the outer surface dotted with scattered thread cells, and there is a velum or membrane between the margins of the bell with a central opening. There are from four to eight marginal tentacles with bulbous bases destitute of ocelli. Four radiating canals are to be seen, and the mouth or manubrium is small and four-lipped.

Other Tubularians belonging to the family Clavidiæ may be instanced by a very pretty species*



FODOCORYNE CARNEA. (After Allman.)

belonging to the genus *Syncoryne*,† which is characterised by having numerous club-shaped hydranths united in a common colony. The tentacles, moreover, are scattered on the clubs and are not in whorls, and the gonophores are in the form of medusæ, with four radiating canals and four marginal tentacles. The little species is of a deep orange colour, and this tint is found on the medusa buds as well as on the hydranths. The little colony is about half an inch in height, and the trophosome has its tentacles knobbed and along the length of the club-shaped part. The medusa buds (gonophores) are in short peduncles, just below the tentacles. These are developed in April, and when the medusa is ready to escape it has four very extensible tentacles at the margin of the umbrella, and is nodulated with clusters of nematocysts. A distinct ocellus is on the base of each tentacle. It is, of course, not covered with a membrane, and is "naked-eyed." The mouth is

short, and there is a membrane or velum extending across the opening of the manubrium with a central opening in it.

Allman found a branching Hydroid in fresh water, and it has since been proved to live in lakes, docks, and rivers in Great Britain generally. It seeks the shade, and is found under logs of wood and attached to the sides of dark cisterns. The whole colony may be one inch and a half to three inches long, but the hydranths continually contract and enlarge, and are very changeable in shape. It is called *Cordylophora lacustris*.

The gonophores which produce the young on the stem are long and oval in shape, and these escape from them, not in the form of medusæ, but as long ciliated bodies or planulæ. The planula or embryo settles down, loses its cilia, and becomes a stem and hydranth.

The last family to be noticed contains a very large and common species belonging to the genus *Tubularia*.‡ The characters of the family are that the hydranth has two whorls of tentacles, one in front of the other. There is a chitinous investment, like a tube, to the root-stem, and the gonophores are in the form of fixed sporosacs, in clusters, reaching down like branches of currants, below the crown of tentacles. These are seen in all stages of growth, and the large ones are the lowest. A zooid escapes from each in the shape of a cylindrical stem with a stellate root and a crown of tentacles, and it grows into a hydrosome. The calyces of the mature form are apt to bend down; one drops off and a new one starts from the wound.

They are very beautiful objects, and the cylindrical stems rise without a branch to the height of several inches, and the tentacular head is scarlet or crimson in colour. Its longer tentacles spread out and retract, and the gonophores droop gracefully amongst them. Spring and summer are the times when this species of the Atlantic and British seas is in perfection, and it is during its most active growth that the tentaculate heads are cast off and renewed.

SUB-ORDER CAMPANULARIA.

The sub-order of Hydroids, which are not only furnished with a chitinous investment over

* *Syncoryne pulchella*.

† Greek, *syn*, together with; *koryne*, a club.

‡ *Tubularia indicica*.

the stems and roots, but have also a hard, transparent, horny-looking structure which environs the top of the polype and protects the tentacles, are the Campanularia. The hydranths thus furnished can retract almost completely in this calycle, and hence they are called Calyptoblastea. The gonophores arise regularly from the gonosomes, which have neither tentacles nor mouth, and some are sessile, and others become free medusæ. Most of these medusæ have marginal vesicles, and produce the sexual elements in the radial canals. The calyces take on most graceful forms, resembling little vases, and often have ornamented borders. The horny cup of the hydranth or nutritive individual or part is called the hydrotheca, and that enclosing the generative buds is called the gonangium.

In many species the aperture is furnished with an operculum, which opens to allow of the passage of the polypite, and closes on its retreat. It is a very effective contrivance, and exhibits two or three principal modifications. In some instances the margin is cleft into a number of pieces, which converge and meet in a point, and form a more or less conical lid. In others the cover is a membranous extension of the walls of the calycle, which falls into plaits or folds when the polypite withdraws, and so roofs over the opening.

STRAW TUBULARIA (*Tubularia indivisa*).

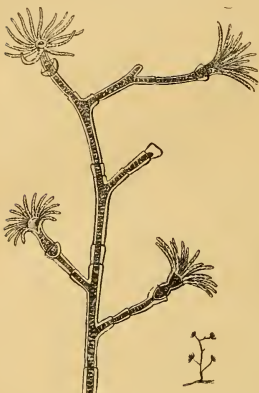
FAMILY SERTULARIIDÆ.

Amongst the Sertulariidae the calycle has a lid or operculum within it, a little below the orifice. It is attached to the interior surface, on one side, and seems to be a continuation of the inner layer. It shuts down over the polypite when it withdraws itself. When the polypite emerges, it slowly pushes the valve back, and keeps it erect so long as it is exerted; on its retreat, which is as quick as light, the lid flies back to its place. (Hincks.) This family has the hydrothecæ sessile, and more or less inserted in the stem and branches. The polypites are completely retractile, and have a single wreath of filiform tentacles round a conical proboscis, and the gonozooids are always fixed.

The great Tooth Coralline is one of these, and belongs to the genus *Sertularella*. The plant-like, branching, jointed stem is rooted by a creeping stolon, and the calyces are decidedly alternate, and have a toothed orifice and a convergent operculum. The reproductive calyces (gonangia) are always more or less ringed transversely. It is of a bright straw colour when living, and is a common shore and deep-water species.* The Tricuspid *Sertularella* is of a delicate habit, light brown colour, and grows

* *Sertularella polygonia*.

to the height of two inches. The calyces are narrow and cylindrical, and the aperture has three denticles. The reproductive capsules are large and very deeply grooved or cut. It is a North Sea form.



PLUMULARIA HALECOIDES (YOUNG). (After Hincks.)

sists of a single chamber, much adherent by its side, and when they are compound there is a tubular portion below, expanding into a hemispherical cup. Some are pedunculate and others sessile. They occur on various parts of the colony, and are usually present in numbers about the hydrothecæ; and in the genus *Aglaophenia* every tooth on the crested ribs of the case or gonangium which protects the gonophore, is formed by one of them. The soft granular mass filling the nematophore has the power of emitting and retracting very extensile and changeable processes.

In the genus *Ophiodes* remarkable thread-like organs are found in great numbers on the creeping stolon, and one is stationed close to the polypite. Each resembles a delicate tentacle, has its narrow base surrounded by a cup-shaped prolongation of the outside tissue of the colony, and is terminated by a knob with thread cells.

In the family Campanularia the hydrothecæ have a ringed peduncle, and the crown of tentacles is below their projecting mouth-trunk. The gonophores are sessile or may become transformed into medusæ, some of which are flat and others bell-shaped.

The family Thaumantidæ has medusæ in the shape of long bells with a short peduncle, the mouth being lobed. There are two long and two rudimentary tentacles in the genus *Lafœa*, and four radial canals, which contain the reproductive organs in the form of ribbon-shaped masses. In the genus *Melicerium* the bell is shorter and broader at the margin, and has a crowd of very slender irregular tentacles. When the eggs are hatched,

* *Sertularia pusilla*.

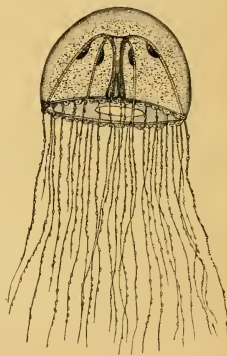
The genus *Sertularia* has the hydrothecæ in two series along the stem, and they are opposite or alternate, without an external operculum. The gonothecæ are large, scattered, and have a simple orifice.

The Sea Oak *Coralline** is a common example, and covers the fronds and stems of the larger seaweeds on the British coasts. It is of a dusky horn-colour.

FAMILY PLUMULARIIDÆ.

The hydrothecæ are sessile, and on one side nematophores exist, and the polypites have a single wreath of filiform tentacles round a central proboscis. The reproductive zooids are always fixed.

Plumularia pinnata attains the height of four or seven inches, and its stems are tall and whitish, and jointed irregularly. The nematophores are sessile and minute, one being below each calycle. The gonothecæ form a double row along the main stem, and have a number of spinous projections at the tip. It is a common species on shells, from low water to greater depths. The nematophores consist of an extension of the body, which may be tubular, or cup-shaped, or conical, open at the upper extremity, and enclosing a granular mass, in which large thread cells may be embedded. Some are simple, and the chitinous cup consists

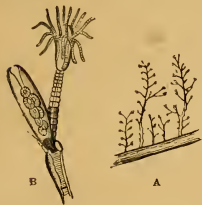


MEDUSA OF A HYDROID. (After Hincks.)

planulae settle down and elongate, a sheath is formed around them and tentacles arise. By and-by the stem branches, and a colony is established, the gonosome stems producing the medusæ in due time.

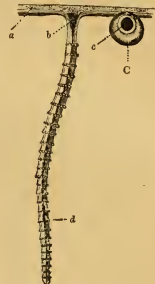
The Equoridæ are the last family, and the genus *Zygodactyla* (twin finger) is its type. The medusæ of this genus are from seven to eight inches in diameter and light violet in colour. The tentacles are long and fibrous, and dark violet, and can be contracted to a mere fringe. They often remain motionless in the water. It is an inhabitant of the North Atlantic and Northern Seas generally.

In the genus *Eucope* the tentacles are well developed, and the calycular membrane which comes up to their bases diminishes in size until it joins the ringed tissue of the stem. On one side of this a long and rather fusiform projection exists, and it has a central body, around which medusa buds form. This gonophore permits the medusæ to escape. They are flat, with a little knob at first on the top, and a few short tentacles are around the disc. Really the knob is the proboscis of the mouth, and the little medusa turns inside out with ease.



EUCOPE DIAPHANA.

A, the colony; n, the young medusæ within the reproductive part. (After *L. Agassiz*.)



MARGIN OF A MEDUSOID.

a, circular canal; b, ocellus; c, sac or lithocyst; d, spherule of lime; d, tentacle. (After *Hincks*.)

SUB-ORDER TRACHOMEDUSÆ.

The Trachomedusæ have a gelatinous disc, which feels decidedly hard to the fingers, and the margin is usually lobed. The tentacles are either rigid or else can move, and there are peculiar sense organs on the base of the tentacles, accompanied by lithocysts, and sometimes by eye-spots. They do not pass through any colonial stage, and the eggs develop into a ciliated larva formed of two layers of tissue, and it has no stomach, but becomes elongated into two arms. After a while two other arms or tentacles are seen, and the central cavity and mouth. Reproductive organs appear, and then more tentacles. There are numbers of these Trachomedusæ in the oceans, and many genera have been distinguished.

In the fresh warm water (86° Fahr.) of the tank which contains the Victoria Regia in the Botanic Gardens of the Regent's Park, London, Mr. Sowerby found great numbers of minute medusæ moving with great vivacity, and preying on the minute crustacea. They were about a line to half an inch in diameter, and had nearly 200 tentacles and four radiating canals and a circular one. There was a velum, and the margin had many eye-spots. The manubrium is long and expanded below, and the tentacles are solid. The genus has been called by Dr. Allman *Limnocoedium*, and Prof. Ray Lankester believes that probably it is one of the Trachomedusæ. It is probably the only instance of a medusa which can live in perfectly fresh water, and which dies in cold or salt water. Nothing is known about its origin.

There are many families of this sub-order, and four may be especially noticed. The Trachonemidæ have the marginal filaments rigid and hardly movable, and the sexual organs develop in vesicular swellings in the eight radial canals, and some have a flat disc with club-shaped tentacles.

Some, like the *Ægina*, with rigid marginal tentacles, belong to the family *Æginidæ*. The stomach-pouches reach far towards the edge of the disc, and the sexual elements are produced by the derm of their sides. Sometimes there is no marginal canal, and four tentacles often exist.

The Geryonidæ have a large cylindrical peduncle environing the stomach. Four or six canals are in the umbrella, and extend from the bottom of the stomach to the radial canals in which the reproductive organs exist. Finally, the Charybdeidæ have the borders of the umbrella with tentacles and compound marginal corpuscles. Ramified canals come from the processes of the stomach. They are dwellers in the Mediterranean and Atlantic.

ORDER HYDROCORALLINA.

The hard, stony, coral-looking substances dotted over with minute pores, and having, within, a tubular structure crossed by platforms or tabulae, are called Millepores. They are reef-builders, and contribute to the solidity of the coral reef structure, dwelling, however, in the warmest waters of the tropics. Formerly classified with the true Corals, they are now, owing to the researches of L. Agassiz and Prof. H. N. Moseley, placed among the Hydroids. The last-named and distinguished naturalist, after having carefully examined the anatomy and development of the Millepores, during the expedition of H.M.S. *Challenger*, classified them in association with certain deep-sea calcareous skeletoned animals, called Stylasters, in a sub-order—the Hydrocorallinæ.



CARMARINA (GERYONIA) HASTATA. (ONE OF THE TRACHOMEDUSÆ.)

This is characterised by the presence of a calcareous base made up of channels formed by the ectodermal part of canals within them. The base is covered with a continuous layer of derm, from which zooids of two forms arise: one with a mouth and gastric cavity—a gastro-zooid; * the other with tentacles and no mouth—a dactylozooid; † they are retractile and lodge in the pores or outer-chambers of the hard part.

FAMILY MILLEPORIDÆ (WITHOUT AMPULLÆ).

The species of the genus *Millepora* are found on Coral reefs, and the dense white substance forming their usually visible portion is of stony hardness, and is marked with numerous pore-like openings, small and sometimes arranged in groups. A dried piece looks worm-eaten on the surface around and between the pores, and these lead down to long tubular cavities, across which flat layers of the same mineral, carbonate of lime, which forms the hard substance, generally stretch one over the other. These are called tabulae, and they separate chambers, the

upper one being free above and open on the surface, and its floor is the last-made tabula. Between the pores and their downward tubular prolongations is a curious hard structure made up of a network of hard tissue, which gives the porous or worm-eaten appearance to the outside. Louis Agassiz and H. N. Moseley both have discovered and described the soft parts on and within this dense white substance, which much resembles, but is not, white Coral. A thin living film covers the whole surface, and a thin downy layer is observed over all, and it consists of minute feeler-like projections arising from the pores. Arranged as these pores are more or less in circlets around a central one, their tentacles differ. The central larger one has a short body provided with a mouth, and it is a cylindrical growth with from four to six short tentacles in one whorl at its top, just below the mouth. Each of these tentacles has a knob at its tip, composed of nematocysts. The small mouth opening is circular in outline, and a little lower down is a cruciform slit environed with gastric cells, bladder-like and transparent. The other bodies surrounding this one, and coming forth from the circlet of pores, are long and slender, cylindrical and tapering. They bear tentacles at regular intervals from top to bottom, each of which consists of a short cylindrical stem with a knob.

No mouth or stomach exists in these long bodies, and their office appears to be to catch food and convey it to the short body with a stomach, in the middle of the circle. All disappear on very slight shaking of the hard mass. The network of the hard substance, supporting these structures, contains soft parts and numerous tortuous canals, and some of these are on the surface and connect the pores together. The hard structure, composed of fibrous-looking carbonate of lime, is produced by the outer skin or ectoderm of the animal, and is nourished by and formed from the digested food, which contains more or less carbonate of lime.

* Greek, *gaster*, stomach.

† Greek, *daktylos*, finger; *zoön*, animal.

The stomach and finger zooids contain muscular fibres, and the nematocysts or thread-cells have a spiral within them, with part of it jagged with a thorny part. Others have three barbs on the thread.

The hard part of the Millepore is called the *cenosteum*. Unfortunately, the method of reproduction had not been ascertained by Prof. Moseley, to whom we owe the very exact description of these interesting things, which were formerly, before Agassiz saw the zooids, considered to be true tabulate Corals. Certainly it is only the part of the *cenosteum* above the uppermost tabula that is alive; all below was so once, and has died.

FAMILY STYLASTERIDÆ (WITH AMPULLÆ).

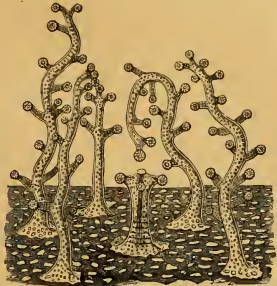
These have the pores with a style or calcareous spiny projection. Ampullæ, or blister-like swellings on the surface, contain the male elements and large planulae.

The Stylasters were named after small red-coloured, more or less fan-shaped, branching coral-like substances, on which are numerous groups of pores surrounding central cavities, having a projection at their bottom. Until Moseley examined them, they were included in the Stony Corals, and the divisions between the pores were considered to be septa. He has proved that the family, which comprises many genera, belongs to the same sub-order as the Millepores. The hard part of the animal is composed of reticulations of tubes, and a gastrozooid occupies the central pore space, and dactylozooids the surrounding circlet of pores. The hard part consists of carbonate of lime to a considerable extent, and is formed by the deposit of it in the substance of the outer skin, or ectoderm, of the canals or tubes. The canals open into the pores, which are really cylindrical pits, and at the bottom of each are a few large canals and their openings. Some genera have a projection, or style, more or less brush-shaped, on the base of the floor of the cavity for the gastrozooid, and resting on a partition or tabula, of which there may be more than one. Small, more or less rounded, projections occur on the surface of the hard part of the animal, and they are the domes covering spaces. These open by slits or get very thin at the surface, and contain the male reproductive elements, or a most remarkable worm-like embryo, which is termed a planula. The planula is large and cylindrical, and being curled up, is larger than the cavity in which it has developed out of an ovum; and this cavity is large in relation to the circlet of pores in some genera. A mature planula is a quarter of an inch in length, and has a transparent gelatinous-looking outer skin, or ectoderm, and a dark-coloured inner, or endoderm. It looks like a worm, and is probably covered with cilia, and there are polygonal markings on the body, and nematocysts. No internal organs exist, and this young form is solid within. It escapes and settles down after leading a free-swimming life, but how the future growth proceeds is not known.

The dactylozooids of all the genera of the family have simple tentacles, which retract, and the gastrozooids are flask-shaped, and may or may not have club-shaped tentacles on them.

These interesting Hydrocorallinæ are found very widely distributed from 10 to 750 fathoms' depth in the North and other parts of the Atlantic and the Pacific Oceans. The West Indies, the coasts of Brazil, and the Japanese Seas are common localities. They may be arranged in two groups. In one the pores occur in regular circlets, or cycle systems, and the genera may again be subdivided into those which have styles present at the bottom of the gastrozooid, and also of the dactylozooid pores. Stylaster and Alloporela belong to this subdivision. Of those with styles only present in the gastrozooid pores, *Stenohelia* is an example; and of those without any styles, *Astylus* and *Cryptohelia* are examples; the last-named genus has a remarkable lip in front of the circlet of pores.

In the second group, the pores for the dactylozooids are either of one or two kinds, and a group of genera belong to each. *Pliobothrus* and *Errina* are examples of the first, and *Spinipora* of the latter condition.



MILLEPORA. (After Moseley.)
The gastrozooid is central, and the dactylozooids are around it.

Fossil Hydrozoa have been discovered, some without doubt analogous to recent forms, and others not so. Impressions of medusæ have been found on the Solenhofen stone, and they were Rhizostomidæ. The Graptolites or Rhabdophora are fossils in the shape of long, narrow, toothed (at the side) bodies, single or combined. They are found in the Lower Silurian, and die out before the end of the Upper Silurian group of strata. Two principal forms exist: those with one row, and those with two rows of cellules; and in Rastrites the cellules are separate, and not overlapping as in the others. They may have a central disc or prong-like process at the end, with a central solid rod. The cellules analogous to the calyces of Sertularians probably contained structures resembling nematophores.

The Hydrocorallinæ of the Millepore division have no satisfactory fossil species; but there is a doubtful form in the Cretaceous rocks. Probably most of the family Favositidæ, usually called Tabulate Corals, were hydroids, and many of the corals called Rugosa.

A fossil, with a root-like expansion, hollow stem, and tentacles, surrounded originally by a calcareous investment, is found on the face of the fronds of a Carboniferous Bryozoon, *Fenestella nodulosa*. It has been named *Palæocoryne*—of the Hydrida.*

GROUP ZOOPHYTA.

CLASS HYDROZOA, OR HYDROMEDUSÆ.

<i>Order.</i>	<i>Sub-order.</i>	<i>Example.</i>
CTENOPHORA	Globata	Pleurobrachia.
	Lobata	Bolina.
	Cestidæ	Cestum.
	Eurystoma	Beroë.
	Monostoma	Aurelia.
DISCOPHORA, OR ACALEPHÆ	Rhizostoma	Rhizostoma.
	Calycozoaria	Lucernaria.
	Physophora	Physophora.
	Physalia	Physalia.
SIPHONOPHORA	Calycophora	Diphyes.
	Discoida	Veella.
TRACHOMEDUSA	Trachomedusæ	Ægina.
		Hydra.
HYDROIDA.	Tubularia—Gymnoblæstea	Perigenimus.
		Eudendrium.
		Hydractinia.
		Syncoryne.
		Tubularia.
	Campanularia—Calyptoblæstea	Sertularella.
		Plumularia.
		Campanularia.
		Eucope.
		Millepora.
HYDROCORALLINÆ		Stylaster.
		Cryptothelia.

CHAPTER II.

THE ANTHOZOA.

Zoantharia and Alcyonaria—Characters—THE ZOANTHARIA—The White Stony Corals or Madreporaria—Structure—The Coral—Development—The Reef-builders—Coral Islands—MADREPORARIA AFOROSA—Turbinididæ—Oculinidæ—Astreidæ—Eusmilinæ—Euphylliaceæ—Stylinaceæ—Lithophylliaceæ—Astreaceæ—Cladocoraceæ—Fungidæ—MADREPORARIA PERFORATA—Eupsamminæ—Poritidæ—Other Groups of the Madreporaria—ANTIPATHARIA OR SCLERORASIC ZOANTHARIA—ACTINARIA OR MALACODERMIC ZOANTHARIA—Characters—Actinidæ—Minyadinae—Actininae—The Sea Anemones—THE ALCYONARIA—Characters—Helioporidæ—Pennatulidæ or Sea-Pens—GORGONIDÆ—Red Coral—Formation—Gorgoninæ—Characters—Various Genera—Alcyonidæ—Distinctive Features—Organ-pipe Coral—Alcyoninæ—Dead Man's Fingers—Classification of Anthozoa.

THE CLASS ANTHOZOA.

THE White Stony Corals, Sea Anemones, and Antipatharia form one order of this class, the Zoantharia; and the Red Coral, the Tube Coral, the Isis, and the Alcyonians are a second order called Alcyonaria; and all of these familiar and beautiful objects merit the name of flower-like animals, from

* The principal works on the Hydrozoa, quoted in this article, are those of Allman (Ray Society), Hincks, and Claus.

their external aspect. All have a home in the sea or in brackish water, and are usually brilliant in colour, radiating in their construction, have tentacles around a mouth which leads to a stomach, and this opens into a large lower cavity, called the perigastric. This communicates with the hollow tentacles, and has the reproductive organs in it. Portions of it are folded at the sides longitudinally, and projections of its membrane, called mesenteries, develop on and within them the ova and spermatozoa. The ova and young escape by the mouth as free ova, or as planulae hatched from them, and not as medusæ. There is an outer skin, or ectoderm; an inner in relation to the stomach, the endoderm; and a tissue between, the mesoderm; and this last secretes, in some, a hard and even calcareous skeleton. The soft structures are usually very contractile, and they contain cellular structures, muscular fibres, much connecting tissue, and scanty, rudimentary nervous elements. There is no special circulatory, respiratory, or excretory system. But the ciliated cells of the outer and inner derms move water over the surface; and in some of the Corals, with a great number of individuals collected in one mass, there are evidences of a water system, which appears to regulate the symmetry of the whole. The derm is crowded with nematocysts, or thread-cells, different as a rule in their construction from those of the Hydrozoa; but some have spiny barbs on the thread, and this is often invaginated more or less before extension. Large and small cells are also present, containing glairy mucus, which escapes on pressure, and colouring matter. The muscular fibres are delicate, without striae, and are longitudinal and transverse, or encircling. The whole soft structure appears to have a power of general or amoeboid movement.

ORDER ZOANTHARIA.

The first sub-order of the Zoantharia is that of the White Stony Corals, or Madreporaria, and the members of it, very numerous in genera and individuals, live on the floor of the sea at all depths down to 3,000 fathoms, and cling to the shore from water level to twenty fathoms. Those which form Coral reefs come under the last assemblage, and the more solitary and simple deep sea Corals belong to the first. All contain in the mesoderm a quantity of hard matter, composed mainly of carbonate of lime in a fibrous or long crystalline condition, called Aragonite; and externally a simple kind will resemble a Sea Anemone. There is a range of tentacles, or more than one, on the top of the body, and a disc within the circle of tentacles, in the midst of which is a small mouth. A coloured tissue, like that of the outside of the tentacles and disc, covers the outside of the body, which generally assumes a cup-like form, or may be flat, bell-shaped, tubular, or compressed like a fan. The disc is marked with coloured lines that appear to radiate from the mouth, and if it is touched with a hard pencil it will contract slightly, and then beneath it is felt a hard structure, made up of a number of plates placed vertically, with their edges upwards. Spaces exist between these septa—interseptal spaces—in which there is a process of the under part of the disc, the mesenteric fold.

On stripping off the disc, the tops of the numerous septa are seen, covered with a filmy structure, and between each pair a soft mesenteric fold.

In the middle of the top of the Coral, and just under the opening of the mouth, is a hard projection, or axis (the columella), or else one does not exist, and the stomach cavity occupies the place. Above the columella, or in its place, is the stomach, lined with endoderm, and having the mesenteries radiating on all sides. Moreover, the tentacles, which are hollow, open into the interseptal spaces, so that the fluid of the stomach can pass around all the soft internal parts and up into the tentacles. The mouth in the disc has muscular sides, and is extensible, and it passes at once by a narrow space to the underlying digestive cavity. Nematocysts and glairy cells and ciliated cells abound in these parts.

The structures outside of the Coral, which are continuous with those of the tentacles above, are thin, coloured, and abound with the same kind of cells as those just mentioned. The whole is under the influence of the moving water, and is aerated by it. Food, in the form of minute invertebrata, comes accidentally in the way, is stopped by the secretion of mucus or by the action of nematocysts, and is moved to the mouth by the tentacles, which grasp it, or by cilia, which simply move it onwards. The mouth opens, and the prey disappears to be digested, and the indigestible parts come forth from the mouth. The juices of the prey are circulated from cell to cell, and add to the bulk of the creature. But the calcareous parts of the prey—its shell, for instance, had it one—and a certain amount of the salts of lime held in solution by the water, are retained in the structures of the mesoderm of the body, and they form the hard Coral. The hard part of the Coral is produced by a deposition of carbonate of

lime in long or short and slender needles, or prisms, in the interstices of a peculiar connective tissue of the mesoderm. Hence these Corals are called Sclerodermic Zoantharia.

By placing a Coral in weak hydrochloric acid and water, effervescence of carbonic acid ensues, and the lime combines with the acid and is dissolved. At last a film remains of the shape of the Coral, and it represents the organic basis of it. An old piece of Coral, when cut in slices for microscopic examination, shows numerous radiating lines once occupied by the organic matter, and starting from them, on all sides, are bunches and masses of the prisms and irregular-shaped needles of carbonate of lime. In some Corals this texture is very dense, and in others very lax and porous; and in these last the texture of the hard part is very spicular, the ends being joined to form a kind of cellular structure. Hence the two great divisions of the Madreporaria: the Aporosa and the Porosa.

The hard parts of the Coral are remarkable for their regular radiation and numerical arrangement. They consist of a theca, or wall, which forms the cup of the Coral, which is closed below at the base, and open at the opposite end, at the calice. The septa, or vertical plates, pass from the inside of the cup towards the central axis. They are free above at the calice, and are sometimes not joined or attached to anything in the centre of the cup, but there may be a columella there, which starts from the bottom of the cup and grows upwards; or it may be formed by the ends of the septa. The interseptal spaces are open from top to bottom in some Corals, and in others there are thin pieces of carbonate of lime, which cross them more or less, and cut off the lower parts from the upper. The animal secretes these, and lives above the upper one. They are called dissepiments.

Outside the cup there are longitudinal ridges in relation to the septa within, which are called ribs or costae; and they may be united by cross bars.

Some Corals are always simple and separate; others, and especially the reef-builders, are compound: that is to say, they propagate by budding from the parent, and then the buds form a succession of buds. A little projection appears on the side of a cup, and soon a few tentacles are seen there. It grows outwards and upwards, and resembles the parent. This is a bud. Other buds arise, and all grow upwards in a bush-like form, and then the buds begin to bud, and so on. There is a symmetry in the growth, and either this bush shape remains, or else structures are grown between the buds and the parent, connecting the whole in a solid mass, called exotheca. They are composed of layers of hard tissue arranged in cellular compartments or cross bars, so as to give great bulk, lightness, and strength to the Coral.

The Corals of all kinds produce ova, which escape from the mouth, and hatch into long ciliated bodies, or planulae. These fix themselves and develop, becoming like the parent. The growth of the individual is accompanied by an increase in the number of mesenteries within the body, and of solid septa between each pair of mesenteries. Two great series of Corals develop septa differently. In one six septa are followed by six smaller, then twelve still smaller are formed, one in each of the already made interseptal spaces, and then twenty-four, and so on, the increase being by cycles in multiples of six. In another series there is a more or less distinct increase by fours, and the position of one or more of the first, or primary septa, is sometimes occupied by a groove. Or there may be a very numerous collection of septa, which appear to be without any rule, and to be alternate in size. In some Corals no definite order can be distinguished. Certain appendages to the septa, between them and the columella, are called pali, and they appear to have reference to a fresh circlet of tentacles.*

The first series are the Hexactinellids, and the second are the Rugosa.

The Corals which live on the southern coasts of England are simple, and do not form reefs, and others of the same genera are found in deep water on the floor of the great oceans. Pressure and temperature seem hardly to influence them, and they flourish in the great depths, in water not much above freezing-point. But the reef-building Corals require a warm sea, and highly aerated, pure sea water, containing an abundance of living things. These conditions are only to be obtained in those parts of the world where the surface temperature of the sea is never less than 68° Fahr., and indeed some Corals require a much higher temperature, such as 72° to 86°. Moreover, the necessary purity of water and freedom from sediments can only be got in the neighbourhood of islands standing in deep water. As the temperature of the sea diminishes rapidly with depth, that of 68° to 86° is not

* An individual Coral, perfect in itself, is a Corallum; a member or an individual which has budded or divided off, and yet still remains as part of a whole, is a Corallite.

maintained below twenty fathoms, and thus there is a downward depth limit to the reef-building Corals. They fringe certain islands within the West Indian, Atlantic, Indian, and Pacific Oceans, the Corals clinging on in great masses to the shore, some being uncovered a little at very low tide, and some extending to the depth of twenty fathoms. The growth is upwards, and outwards, or seawards, and sometimes to a considerable extent. Such a mass of Coral is alive on the top and where in contact with the sea; but all the supporting mass which once was alive is dead, and consists of a mass of hard Coral, united by exothecal structures, and much altered by the percolating water.

In some parts of the Pacific Ocean, an island is seen surrounded by a calm lagoon of sea water of no great depth, and in the offing is a more or less circular reef, with openings in it. This is a Coral structure which is growing, but does not extend deeper than twenty fathoms in the living state. But the foundation of the distant reef extends from it to the island, and underlies the living and dead mass of Coral. These are barrier reefs. In other parts of the great ocean simple rings of reef, called atolls, are seen. There is no mountain in the midst, but a lagoon. The fringing and barrier reefs are phases in the development of the atoll. The land was once surrounded by a fringing reef, and subsidence commenced. The Coral, ever growing, increased in bulk upwards, growing as the land sank, and this process gradually necessitated a shallow sea between the mountain tops and the reef. This barrier reef, still subsiding with the mountain, on which it hung amidst the waves, yet ever growing upwards, at last witnessed the total submergence of the land. An atoll thus formed is a vast mass of Coral covering a sunken island, the living Coral forming a ring around a lagoon, with openings seawards. This is the theory of Charles Darwin.

The most rapidly growing Corals live in the surf and most heated water on the outside of the reef, and the more solid reef-builders remain in quieter water, in the lagoon. Many simple Corals are found amongst the reef-builders, and live in company with a vast assemblage of Tubicolar Worms, Echinoderms, Anemones, and Crustacea; but the beautiful aspect of the reef, with its gorgeous colours of green, yellow, violet, and gold, is produced by the soft discs and stems of the Madreporaria and Sea Anemones.

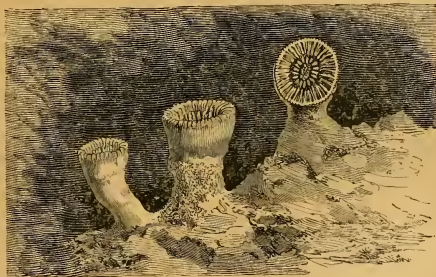
The Madreporaria are very numerous in genera and species, and they may be divided into those which have the hard parts dense, and into those with a light skeleton, very porous in its nature, and reticulate in its construction. These divisions are those of the *Aporosa* and *Perforata*. A great group, now almost extinct, but which preceded those just mentioned in time, is that of the *Rugosa*.

THE GROUP MADREPORARIA APOROSA.

FAMILY TURBINOLIDÆ.

These Corals are usually simple and solitary, but some have offshoots in the form of buds, which resemble the parent. They are not united by exotheca, and there are no internal dissepiments in the interseptal spaces, exceptions to this statement being excessively rare.

The common so-called Madreporæ of the Devonshire coast,* and those which are dredged up out of moderately deep water in the North Atlantic, are common examples of the genus *Caryophyllia*, which do not usually increase by budding, but by the development of ova. Those species, which are fixed on to substances on the floor of the sea, often have a delicate outer layer of hard tissue, called an epitheca, and nearly all are very beautifully ornamented, and some



CARYOPHYLLIA CYATHUS.

* *Caryophyllia smithii* (Stokes).

have a spiny outside. This genus is the type of a sub-family* in which there is a row of pali, and it is found that the interseptal spaces, when the soft parts are washed away, are open throughout. One genus† increases by budding, and is therefore compound.

A sub-family which is but slightly represented now, and which had a great development in the Secondary and Tertiary ages, is that of the Trochocyathaceæ, and it has more than one row of pali, and consequently as many extra rows of tentacles. Several of its genera are now represented in the deep sea, and Deltocyathus is the most widely distributed, being found, moreover, at the depth of 2,250 fathoms.

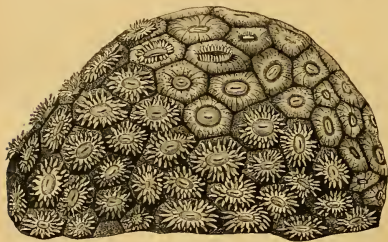
Another sub-family is that of the Turbinolinæ, and it is characterised by the simplicity of the hard parts, there being the cup or wall, septa, and costæ. Sometimes the columella exists, and an epitheca, but pali are not seen. Some of these simple forms are extinct, and the majority still live. They are divided into genera by the shape of the Coral, which, for instance, is compressed and fan-shaped in Flabellum and wedge-shaped in Sphenotrochus; and by the nature of the columella, which is styliform in Turbinolia and fascicular in others. Some, such as Blastotrochus, bud on the outside. Many of the species of this sub-family are dwellers on the floor of the deep sea, and the fossil forms are very numerous. The third sub-family is that of the Dasmidæ, and the only genus is extinct.

FAMILY OCULINIDÆ.

These are branching Corals, which bud on the outside of the stem, or on the edge of the calices, and have these last resembling, more or less, those of the family just noticed. There are, however, dissepiments in the interseptal spaces of some, and in the common *Lophohelia prolifera*, found on the floor of the North Atlantic, horizontal layers of hard tissue may cross the whole internal cavity, and are called tabulæ. Moreover, the lower parts of the cup fill up with carbonate of lime, and there is a general solidity of the branches. The genera are numerous, and many are extinct, whilst others inhabit great depths. A small sub-family, the Stylophorinæ, increase by the process of budding, or gemmation, but the hard tissue is not so compact as that of the others, and the columella is styliform.

FAMILY ASTRÆIDÆ.

This family consists of a vast number of genera, many of which are reef-builders; others are simple forms, and several are extinct. The hard parts have all the structures hitherto mentioned,



FAVIA PALLIDA.

and divide, and the separate portions become isolated more or less above, but still remain parts of the original Coral. Some form tuft-shaped Corals, free, to a great extent, at the surface, and others are only isolated at the calicular surface, and form masses, and a third group are completely fixed and confluent, forming very diverse-shaped Corals.

Another sub-family is that of the Styliaceæ, which was largely represented in the Mesozoic and

and there are septa, costæ, a columella, endothecal dissepiments, epitheca, and buds. There is also exotheca in the compound forms. They are divided artificially into two groups: those with the tops of the septa plain—the Eusmilinæ—and those with serrations, or spines, on the tops of the septa—the Astræinæ. The first sub-family of the Eusmilinæ is a very ancient one, the Trochosmiliceæ, and they are solitary Corals, cup-shaped, and with the internal dissepiments well developed.

The sub-family Enphylliaceæ grow in bulk by fissiparous division of the calices. These elongate in one direction

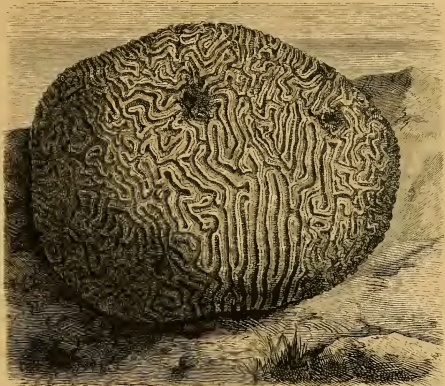
* *Caryophylliaceæ*.

† *Canocyathus*.

Tertiary ages, and which is almost extinct. They grow regularly and without the fission; the buds become polygonal as they grow upwards in company, and they mostly have a styliform columella. Some of these were great reef-builders of old, and the buds and parents were all united as a cellular mass, by exothecal structures and by epitheca. One exceptional genus still flourishes, and in this the buds, or corallites, are free above, and all united below by a dense growth, like an exotheca, the growth being termed peritheca. It is the common *Galaxea*.

The group *Astreine* have spines and serrations on the free edges of the septa. It is a very unsatisfactory division, but it is remarkable that the sub-families of the *Eusmilinæ* are represented in the *Astreine*, the difference being only in the septal structure. They are usually massive compound Corals, and dwellers in shallow water and reefs. But there are some which are simple and solitary, and they belong to the sub-family *Lithophylliaceæ*, which, however, contains compound forms also. This sub-family has some of its Corals in tufts and others in lines or series more or less confluent, and these last are subject to growth by fissiparity, the calices being often very long and curved, or meandriform. The genera *Montlivaltia* and *Antillia* belong to the simple kinds, and the first has fossil and the second both fossil and recent forms. The

tufted *Montlivaltia* group are represented by the *Mussas* of the warm seas of the great oceans, and by the extinct genera *Thecosmilia*, *Rhabdophyllia*, and many others. Many massive Corals, with many small calices arranged in long, wavy, trough-like series, exist amongst the meandriform group, and are classified under the genera *Symphyllia*, *Mycetophyllia*, *Isophyllia*; and in some the septal edges are extremely spinulose. The very solid-looking, wavy-caliced *Mæandrinæ* belong to this group, and the common Corals so frequently sold at sea-side places, with slightly elongated deep calices, belonging to the genera *Lepetoria*, from the Red Sea and Pacific and Indian Oceans. The



DIPLORIA CEREBRIFORMIS.

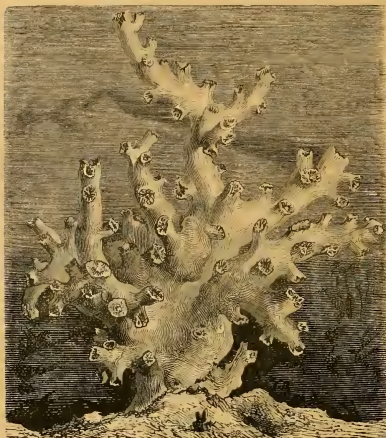
Brain Stone Coral (*Diploria cerebriformis*) is one of these. Numerous fossil species of still existing or extinct genera are recorded.

Another group of these ragged-topped septate Corals increase by the division of their calices, but grow up in a solid mass, the division being restricted, and all the resulting individuals being united together by exotheca. Some of these have the costæ of one corallite uniting with those of their neighbours, and pali may exist. Some Atlantic, Red Sea, and Pacific Ocean shallow water Corals of this group are the *Faviæ*, and there are extinct species also. The lobed *Goniastrea* belongs to this series.

The sub-family *Astreaceæ* are Corals with spiny or serrate septal edges which reproduce by ova; but the individual is enlarged by a process of budding, which may take place from the outside of the Coral, and from just outside the margin and from within the calice. The buds grow, and are united by a dense exotheca, and the solidity of the whole is often increased by the costæ of the corallites, or separate parts of the mass, being united. The calices are separate in some genera, as in *Heliastrea*, and in such as bud outside the calice. Others, which bud within the calices or at the margin of them, have polygonal, elongate, and even very confused calices, and they may be joined by the

costæ passing from one calice to another, or by special structures. The genera *Astræa* and *Prionastræa* amongst the recent Corals, and *Isastræa* and *Thamnastræa* belonging to the extinct fauna, are familiar examples.

The *Cladocoraceæ* are a sub-family with dendroid-shaped Corals, and some of the genera are extinct. *Cladocora cespitosa* is a well-known species of the Mediterranean, and other species inhabit the West Indian Seas and Madeira. Some of the spined septate Corals bud in a remarkable manner from a kind of creeping root, or stolon, and the corallites thus arising may or may not be covered with epitheca. These are the sub-family *Astrangiaceæ*, and the genera *Cylicia*, *Cryptangia*, and *Astrangia* are types, some species being extinct. Finally, two little groups, the *Echinoporeæ* and *Merulinae*, are the last of the series, and lead, by their structural peculiarities, to the next family.



DENDROPHYLLIA RAMEA.

FAMILY FUNGIDÆ.

This family is characterised by the flat growth of the corallum, and especially by the occurrence, in the interseptal spaces, of stout, straight dissepiments, simply stretching across from septum to septum, like little beams. These are *Synapticulæ*. There are two sub-families. In the first, the *Funginæ*, the under part of the wall or base is more or less porous and spinulate. The common large simple Coral (*Fungia patella*), so like a flat mushroom, which is found very

generally on the shores of the Eastern seas, is the type. Another, elongate in shape, has been compared to the Sea-slug, and is a large Coral.* Several genera are extinct, and *Micrabacia* of the Chalk is an example. In the sub-family *Lophoseriinae*, the wall is entire and not spinose, and it contains some twenty genera. Some have the species simple and cup-shaped, or button-shaped; others are compound. *Agaricia* is a typical genus. Moseley obtained a beautiful Coral (*Bathyaëctis symmetrica*) from a wider range than any other known Coral—from thirty fathoms to three miles of depth, and in all the oceans. There are instances amongst the *Fungidæ*, as well as in the *Aporosa*, where the buds become disconnected from the parent, and form other and independent Corals. The family was represented in the early Secondary formations, and has persisted.

GROUP MADREPORARIA PERFORATA OR POROSA.

The group of the Perforate Corals, whose hard texture is reticulate and open, is subdivided into two families. In one, the *Madreporidæ*, the wall is porous, but the septa are more or less lamellar and entire; and in the other, the *Poritidæ*, the wall and septa are both reticulate and porous.

An important sub-family of the *Madreporidæ* is that of the *Eupsamminae*, in which the smaller and younger septa curve towards the older ones close by, so that a very elegant pattern is formed. The *Dendrophyllia* dredged up in the Mediterranean and off Madeira, which has a curious scent, belongs to this sub-family, and the most beautiful Corals known, the *Stephanophylliæ*, also. These are found living at considerable depths at the present time, and there were exquisitely beautiful species in the Secondary and Tertiary ages. A very remarkable form, called *Leptopenus discus*, a

* *Herpetolitha timax*.

very elaborate piece of coral lace, flat and wonderfully fragile, was got up from 2,600 fathoms in the Indian Ocean, and described by Moseley as one of these. The branching Madrepores belong to a second sub-family, and they are the most vigorous of the reef-builders, living on the outer edge of the reef, and attaining great bulk. Some live in quieter water.

The second family, the Poritidae, is composed of two sub-families: the Poritinae, with little or no tissue between the corallites, which are tolerably close together, as in *Goniopora*; and the Montiporinae, which have a spongy intermediate tissue. Nearly all the species are reef-builders, and all are shallow water dwellers. Porose Corals existed in the Palaeozoic age.

Other great divisions of the Madreporaria are the Tabulata, Tubulosa, and Rugosa.

It has been noticed, in treating of the Hydrozoa (page 292), that some of the Tabulata belong to that class. There are some of this great group of the Corals which cannot yet be classified satisfactorily. Some certainly belong to the Alcyonaria, a group which will be considered in a future page, and one genus, *Pocillopora*, which has tabulae and twelve tentacles, with very rudimentary septa, probably should be referred to the Aporose division of the Madreporaria. Others of the old group Tabulata may be Bryozoa.

The Tubulosa contain two genera, which are extinct, namely, *Aulopora* and *Pyrgia*, but their classificatory position is very undecided, and probably they were Alcyonarians.

Lastly, the Rugosa, a grand group in the Palaeozoic age, in which they were reef-builders, has some modern representatives in the small *Guynia* and *Duncania* of the floors of the Mediterranean and Atlantic Ocean.

SUB-ORDER ANTIPATHARIA, OR SCLEROBASIC ZOANTHARIA.

These are mostly slender and branched animals, fixed on to substances at considerable depths, and very plant- or bush-like in appearance. The inside of their stem is solid, and is composed of hard concentric layers, with a central space, and may be corneous or calcareous. It is covered with soft tissue, which is continuous with the polypes which form the outer living part. The whole is, as it were, a colony, and there is great symmetry in its size, colour, and arrangement. The polypes resemble small *Anemones*; no hard parts are within their derm, and their base rests on and forms the solid stem or axis. They have six to twenty-four simple tentacles. In the genus *Cirripathes*, the shape of the stem is that of a stick, and it is covered with little sharp spinules; and in one from the Fijis the stem is very flexuous, and is often spirally curved, the polypes are green, and the tentacles brown, and the surface is ciliated. The genus *Antipathes* has a black, hard stem, like ebony, and it is more or less echinulate, and ends in small barbules. The species differ in the kind and amount of branching, and whether they are spiny or not. They live on the floor, at moderate depths, of the Atlantic, Pacific, West Indian, and Indian Oceans, and the Mediterranean Sea. Six tentacles are present, and two mesenteries. In the genus *Gerardia* the hard stem is branched and rough like shagreen, and the soft tissue is dense, and contains silicious spicules; but they appear to belong to other animals, and are accidental. There are twenty-four tentacles, and as many mesenteries. The species are from the Mediterranean and West Indies. A vitreous or semi-hyaline-looking stem, more or less fan-shaped in its branching, characterises the genus *Hyalopathes*, of the Indian Ocean. In all these genera the hard stem is the product of the base, or lower part of the outer skin of the soft polype-bearing textures.



MADREPORA PLANTAGINEA.

SUB-ORDER ACTINARIA, OR MALACODERMIC ZOANTHARIA.

This sub-order has its members without any hard calcareous deposit in the mesoderm and base, and the soft parts closely resemble those of the Stony Corals. In some instances there are

calcareous spicule in the tissues. There are two families: the Actinidæ, with the tentacles in several alternating cycles, each corresponding to a special perigastric locus; and the Cerianthidæ, whose tentacles are in two concentric circles, so that an inner and an outer tentacle arise from the same perigastric locus, and their internal cavities are continuous. The mesenteries do not descend to the bottom of the visceral cavity, and the base of the animal has not a fleshy sucker, but the lower part is more or less slender, and is placed in the mud or sand.

In the genus *Cerianthus*, of this last family, the base is perforated by a channel, opening externally in a pore, and this very exceptional structure in the Actinozoa is for the purpose of getting rid of undigested matters. A kind of flexible sheath is found around the species, and is produced by an aggregation of nematocysts cast



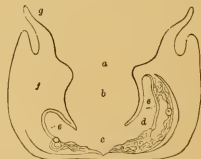
ANTIPATHES ARBOREA.

forth by the skin. They are principally inhabitants of the Mediterranean, but a species was found at 2,780 fathoms in the Atlantic, and was described by Moseley. It was dwarfed, its anatomy was exceptional, and it was contained in a tube made up of the threads of its nematocysts.

The great family of the Actinidæ is subdivided into two groups. In one the bodies have a disc at their base or foot, and are more or less separate; and in the other there are sclerites or hard spiculæ in the tissues, which give a coriaceous texture to the mass.

In the other bodies have a disc

Amongst the first division are the Minyadinae, which do not fix themselves by their base or foot, but, by contracting it, form a more or less hollow space. Air is taken into this cavity, and the animal floats freely, with its tentacles and mouth downwards. The blue Minyas* of the Cape of Good Hope is melon-shaped, and flattened above and below; it is blue, with white projections on it. Moseley described a floating form, with a cylindrical body and flattened base, which was obtained during the *Challenger* Expedition off the north-east of Australia, and one from 700 fathoms. The next division is that of the Actininae, the great majority of which have an adherent base, which they can fix and unfix, and they have one kind of simple tentacles. At least twenty-four genera are included in this division, and there are a vast number of



VERTICAL SECTION OF SEA ANEMONE.

a, mouth; b, cavity of stomach; c, body cavity; d, intermesenteric chamber; e, generative filaments; f, mesentery; g, tentacle.

* *Minyas cœrulea*.



SEA ANEMONES.

1, *Cereus* (*Bunodes*) *coriacens* = *crassicornis*; 2, *Adamsia parasitica*; 3, *Actinia* (*Metridium*) *dianthus*; 4, *Sagartia vidusta*; 5, *Sagartia rosea*; 6, *Cereus gemmaceus*; 7, *Anemonia cereus*.

species. The well-known genus *Anemonia* has an adherent base, and is without any pores in the sides of the body, which are smooth. Its tentacles, very numerous, are not retractile, but long. The margin of the tentaculiferous disc has no coloured bodies, and the tentacles are conical. It was called *Anthea* by Johnston. *Anemonia cereus* has from 100 to 200 tentacles longer than the body, and they are green, or olive and brown tipped with rose, with a brown disc, with green radii. It inhabits the rocks of the English Channel. *Anemonia medea*, with short tentacles, inhabits the Scottish coasts. Other genera have coloured bodies on the outside of the disc.

The genus *Actinia* has tentacles that can be retracted, and it has the chromatophores, or coloured bodies. *Actinia mesembryanthemum* is the common Red Sea Anemone of the south of England, and it is a hardy thing, liking to get out of the water now and then on to the rocks, and to remain there closed, and then to re-enter by crawling with its disc. It is very voracious, and grows to a moderate size, and lives years in confinement.

Actinia anguicomma and *A. pallida* are also English species.

The genus is found in all the northern seas, the Mediterranean, the Atlantic, and on the Pacific coasts.

Moseley has described *Actiniae* from 1,075 to 1,350 fathoms' depth in the Atlantic, clinging on to the stems of a Mopsea.

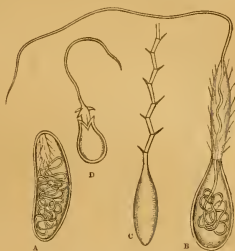
The genus *Paractis* of the South Seas and Atlantic has no chromatophores.

The pretty *Dianthus* Anemone belongs to the genus *Actinia*, and has its disc lobed. An allied genus is that of *Discosoma*, and it contains a huge form, which measures two feet across, and which lies flat like a carpet on the mud of the Red Sea.



ACTINIA MESEMBRYANTHEMUM.

known for its beautiful colours, green, grey, and red, its numerous pointed tentacles, and its voracity. Unfortunately it does not live well in aquaria. It has neither chromatophores around the disc



THREAD-CELLS OF SEA ANEMONE.

A, quiescent; B, C, D, ruptured.

This genus is Mediterranean and Pacific in its distribution.* The genus *Corynactis* has the tentacles swollen and sub-spherical at their ends, and *Melactis* has a protractile mouth and knobbed tentacles. An epidermic envelope surrounds the red *Capnea sanguinea*, and a *Dysactis* from Guernsey † has a long body, narrow below, with two crowns of tentacles very distinct, but contiguous at their origin. The largest are filiform and white, and the others are small and orange in colour.

Several genera have wart-like tubercles on the sides of the body, which secrete a sticky substance, and the base, or foot, is very well developed.

The Crassicorn ‡ Anemone of the south coasts of England belongs to the genus *Cereus* (*Bunodes*, Gosse), and is well

* The deep sea genus *Corallimorphus* of Moseley (2,028 fathoms) belongs here.

† *Dysactis biserialis*.

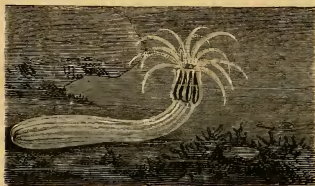
‡ *Cereus crassicornis*.

nor pores on the outside. A small green species, banded with yellow, is found on the British coasts, and its tentacles are banded with white and green. The warts are arranged in vertical series.* The Gem Anemone † of England has small warts in close longitudinal series, and the tentacles, which are slender, are ringed with white and green tints. The Daisy Anemone ‡ can elongate its body considerably, and has a delicate integument of a pale grey yellow, and the warts are restricted to close to the upper part. The disc can alter its shape considerably in a wave-like manner, and the tentacles are very numerous, delicate, smallest externally, and they are ringed with grey and white tints. Another species, *Cereus venusta* (*Actinia venusta*, Gosse), has a brownish orange-coloured body, very numerous tentacles, and it emits an abundance of filaments with nematocysts, when it is irritated.

Several other species are found in the English Channel, and the genus frequents nearly all the shores of the great oceans.

The genus *Phymactis* differs from *Cereus* in having chromatophores around the disc, and the species are from Peru, the Cape, St. Helena, Brazil, and Australia. *Cystiactis* has large prominent tubercles on the body, and has a South American distribution. An Anemone which usually selects an empty whelk-shell to fix its base upon, has a leathery consistence of body and short tentacles; the tints are greyish-yellow, banded with red-brown, and the tentacles are banded with the same colours. It has pores situated near the disc. It is *Adamsia effeta*. Another species inhabits the surface of shells in which the Soldier Crabs reside, and its very flexible body has the disc bordered with a rosy orange tint.§

All the remaining genera of Actiniæ have a very small base and an elongate body.



EDWARDSIA CALLINORPHA.

The species of *Iuanthos*, known in the Scottish and English seas, differ: in the one the body is elongated and pointed at the base, and the filiform green tentacles are in one row;|| and in the other the body is squat, with a small base, and the tentacles are thick.¶ These Anemones are deeply fixed in sand and mud. The *Edwardsias* have the body attenuated at the base, but there is a dense dermal structure, more or less opaque, into which the animal can withdraw its two ends. In the genus *Peachia* the body is long, and there is a central orifice in the slender base. The tentacles are in one row, and the mouth has a papilliferous and

protractile lip. *Peachia hastata* lives in the sand, with the calice just visible, in the English Channel. It appears that the young form of one of the *Edwardsiæ*, has eight tentacles, and only two mesenteries.

The sub-family *Phyllactinæ* contains Anemones which have some of the tentacles branching, or compound in their structure. In the genus *Phyllactis* the simple tentacles form an inner row, and the compound leathery ones, an outer crown. The *Thalassianthinæ* have all the tentacles ramose or papillate. Finally, the *Zoanthinæ* are aggregated polypes, which increase by budding at the base, and they have a coriaceous false skin, in which the secretions are mixed with concretions of sand and shells.

* *Cereus chrysoplenium* (Johnston).

† *Cereus* (*Bunodes*) *gemmaceus* (Gosse).

‡ *Cereus bellis*.

§ *Adamsia palliata*.

Some of the Actiniæ, such as the genera *Actinia* and *Cereus*, have the ova and spermatozoa developed in the same animal, and other genera are unisexual. The ova undergo their early changes in the parent, and a ciliated planula is set free. An oval depression appears at one end of it, which becomes the mouth and gastric sac. There is a tuft of cilia at the base end, and the planula swims with it forwards. Then the mouth elongates in one direction, and two mesenteries are formed out of the mesoderm, so that the planula is bilaterally symmetrical, and has an internal cylindrical canal communicating with a bilobed perigastric cavity, which separates it from the body-wall. Another pair of mesenteries make their appearance in one of the spaces between the two mesenteries, and thus four mesenteries and four inter-mesenteric spaces are formed. Then a pair of mesenteries appear in the other space, so that altogether there are six. Then two more are added, and there are eight mesenteries and chambers. Subsequently a fifth and sixth pair are developed, and twelve mesenteries result. Seven of them have come from the division of the first primary, and five from the second primary chambers. These researches by Lacaze-Duthiers connect these presumed radiate animals with those having a bilateral symmetry, and group together the Anthozoa with four, six, and eight tentacles or their multiples.

|| *Iuanthos scoticus*.

¶ *Iuanthos mitchelli*.

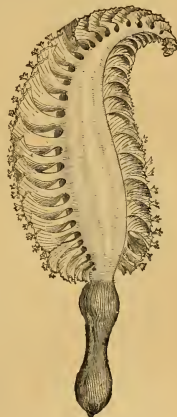
THE ORDER ALCYONARIA.

The numerous members of this order are well distinguished by having eight tentacles, or tentacles in multiples of four, which are very regularly pinnate. They form a single row, or cycle, and are enlarged at their base, and each communicates with one of the eight perivisceral spaces around the stomach. Certain boat-shaped spicules are found in groups, at the base of the tentacles and in the derm, and are often coloured. The mouth varies in its shape, but has not a bilobate form. The stomach terminates, internally, in an orifice surrounded by a sphincter (pylorus). Eight mesenteries project from its outer surface into the perivisceral cavity, and reach the walls of the body to which they are fixed. Each inter-mesenteric space is continuous with a hollow tentacle above, and below it communicates with the visceral chamber near the pylorus. The visceral cavity beyond the pylorus is variable in its size; in the genus *Corallium* and in the *Gorgonias* it is short and rounded below, but in *Alcyonium* it is long, and narrow in shape. The body is very soft and retractile at the upper part of this portion of the cavity, but at the lower part the dermal tissues contain sclerites and spicules. A calcareous stem often results, which may branch, and become thick and concentric in its structure, or spicules may simply strengthen the integuments, and in the first family coral-like structure exists.

The family *HELIOPORIDÆ* contains the so-called Blue Coral (*Heliopora corulea*), which is found on many Pacific coral reefs. The *Heliopora* has a massive, hard, calcareous skeletal structure, with pores on its surface leading down to tubules, which are crossed by tabulæ or horizontal floors. The soft parts cover the hard, and dip down within the pores and to the level of the uppermost horizontal tabula. The pores have little projections, like imperfect coral septa, and there may be from twelve to sixteen. But at a slight depth in the calice Moseley, to whom we owe the anatomy and zoology of the group, says the projections become eight in number, and in the living animal a mesentery passes to each internal projection. The soft tissues of this hard cellular mass are composed of an ectoderm, mesoderm, and endoderm. The first is superficial, and is also prolonged to form a lining to the stomach. The mesoderm has connective tissue, layers of cells, and masses of fibrillar tissue, and the carbonate of lime of the skeleton is produced in the first. The endoderm forms layers lining the centre of the tubes of the hard parts, the calices, and the interseptal spaces. There are deep superficial canals on the top of the hard skeleton, communicating with the calices of the pores, and they are lined with the three dermal elements. The polype with its tentacles has not yet been seen expanded, but Moseley has drawn the unexpanded condition, and has shown that retractor muscles exist, which withdraw it into the pore, down to the upper tabula. Very small nematocysts occur in the ectoderm. There are eight lobes in the unexpanded polype, and eight tentacles exist, and there are evidences of short stout tubercles on them. Moseley found ova in about three polypes out of a hundred, but no spermatozoa; so in all probability these tabulate Alcyonaria are unisexual.* The fossil genus *Heliolites*, of the Palæozoic age, is a close ally of the *Heliopora*, which has itself been found fossil in Secondary rocks.†

THE FAMILY PENNATULIDÆ.—THE SEA-PENS.

These are free-swimming, more or less pen-shaped Alcyonaria, and some live with their slender pointed root in the sand and mud, but they are not fixed. Their surface is soft, and may have three kinds of polypes, or zooids, upon it, continuous by their bases. They are connected with the central stem, or axis, which is fistulose, and made up of horny and calcareous matter, traversed by

PENNATULA (PTEROIDES)
SPINOSA.

* H. N. Moseley, F.R.S.: Report on Corals, *Challenger* Expedition.

† Allusion has been made to the *Tabulata* as a group already; and Moseley's researches almost necessitate the placing of the *Favositidae* of Milne-Edwards and Jules Haime amongst the Alcyonaria, so that the group is very old, and was Palæozoic. Some forms, however, are Bryozoa.

soft tissue in bands. The lower part of the axis is not covered with zooids, and the upper part may have its surface with zooids on one or both sides in simple series, in spiral series, or in groups on one or both sides. When the upper part of the axis is branched, the pen-shape may be single or double, and crowds of zooids with spinules are arranged on one edge. The ectoderm usually contains calcareous spicule. The Sea-pens live in shallow water, and also at great depths, and their distribution in the ocean is very wide. The sub-family Pennatulæ contains the genus *Pennatula*, in which the zooids are on the ventral and lateral sides of the stem, there being always a bilateral arrangement of them on the long cylindrical pinnate stem also. Many are very phosphorescent, and most live in shallow water, some going down to three hundred fathoms. Their colours are often brilliant red, and the specimens may be a foot in length. The stalk, or lower part of the axis, swells out, and then terminates in a slender end, or it may be short and cylindrical. The spicules have the tint of the whole. The zooids are on the tufts, and not on the stem, in the genus *Pterocoides*. In the genus *Virgularia* the root is stout and bent, the axis very long and often curved, and the zooids are on either side, on the short pinnules. Calcareous needles are scanty in the stalk and tentacles. In the genus *Scytalium*, the zooids, placed side by side, resemble the half of a young leaf, and the pinnæ are thick, whilst in *Pavonaria*, the zooids are on the thick edge of the four-sided stem. A magnificent

form, called *Anthoptilum thomsoni*, after the late director of the *Challenger* Expedition, has a round and long axis, and the zooids are in many short rows on it. It was found at six hundred fathoms' depth, south of Buenos Ayres, and another species at a depth of 1,200 fathoms. The family *Umbellulidæ* have a long sterile axis, and from about twenty to fifty zooids are grouped together at the upper end, in a more or less umbrella form. Some species were found at a depth of from 1,200 to 2,125 fathoms.

The family *Renillidæ* have a kidney-shaped body, without a solid axis, and the zooids are on one side of their single pinnule. The *Veretillidæ* have an elongate axis, which has retractile zooids over the entire surface, and its lower part is bulbous, naked, or soft. It is divided longitudinally by two intersecting membranes, with a calcareous axis in the lower part of the stem, or it may be simple and fleshy.

THE FAMILY OF THE GORGONIDÆ.

There are vast numbers of branching, slender-stemmed, compound *Alcyonaria* living fixed on the floor of the sea at different depths. They have a cellular soft part, in which are the zooids, or polypes, with eight pinnate tentacles, and this surrounds, in the manner of a bark, a more or less horny or calcareous stem, which is fixed at its base. The soft tissue is furnished with sclerites or spicule, and a canal system is on the outside of the stem, or sclerobasic axis. It appears to have to do with the general nutrition and symmetrical growth of the whole, and probably it communicates with the visceral cavities of the polypes. The visceral cavities of the polypes are short, and rest, as it were, on the outside of the central stem. There are two great divisions of this



UMBELLULARIA GROENLANDICA.

family; in one the axis is flexible, horny, and only partly calcareous, and in the other it is completely calcareous. The first division relates to the sub-families *Gorgoniæ* and *Isidinae*, and the last to the sub-family *Corallinae*.

The beautiful Red Coral,* which is used so much as an ornament, is the cleaned hard stem of an Alcyonarian, which lives fixed to substances at considerable depths in the Mediterranean and some parts of the Atlantic and Pacific. The red stem has delicate striations on it, and a section shows a concentric arrangement of calcareous matter, tinted various shades of red. The animal forms this by deposition of the calcareous grains in a connective tissue, and covers the whole with a somewhat dense soft part. In this there are canals, or water-systems, running over the hard stem, conforming to its markings, and communicating with smaller canals. The soft parts, moreover, above the canals are formed into polypes, or zooids, which are contractile and very extensible. They have a thick base, which narrows upwards to a point, whence a swelling extends, capped by eight feathery tentacles. Muscles exist to retract the zooids, but nerves have not yet been distinguished. A mass of spicules environs the hard stem, and is gradually connected to form the outer layer. The zooids are unisexual or bisexual on the same stem, and the ova form a planula covered with cilia, like a little white worm. It swims freely, and settles down after escaping from the mouth of the parent, remaining permanently adherent to some substance on the floor of the sea. The changes then proceed which lead to the formation of a mouth, stomach, and perigastric cavity; and the calcareous matter gradually deposited by connective tissue, and forming the stem and the spicules, is derived from the products of digestion. As in the case of the Stony Madreporaria, the carbonate of lime of the skeleton is not got from sea-water, but from the shells of the minute animals which constitute the food. The deposition of the carbonate of lime thus obtained in certain tissues is analogous to the formation of bones in the Vertebrata and shells in the Mollusca. There is a very important coral fishery off the coast of Algeria, near Calle, and also off the east coast of Spain, and the article is systematically obtained by a rude dredging or breaking-off and bringing-up apparatus. The coral fisheries of the coasts of Italy and Sicily begin about the middle of February and continue into October. Pale coral is the most prized now. Off Torre del Greco a large quantity of coral is found every year, and from 400 to 600 boats of from six to ten tons are employed. The cost per boat is from £500 to £600, and the Coral, when good, is worth from £80 to £200 an ounce. Dana describes a branching, more or less fan-shaped Coral, of a pale colour within and brilliantly red outside. It is also found off the Sandwich Islands. These species belong to a sub-family—the Corallinæ—and it was represented in the age of the Chalk at Faxoe, and in the Miocene of Turin and Sindh.



CORALLIUM RUBRUM.



CORALLIUM SPICULE.

Other dwellers on the floor of the sea, possessing branched stems, have the calcareous part of it not continuous, but in more or less cylindrical or flat pieces, separated by horny tissue. They are the sub-family Isidina; and the genus *Isis* has the polypes on the calcareous pieces which are striated. The branches arise from the calcareous parts. *Isis hippuris* is from Amboyna, and *Isis polyantha* from the American seas, whilst *Isis coralloides* is from the seas of India. This widely-distributed genus has naturally fossil forms, and they have been found in the Cretaceous and Miocene strata of Europe, and in the Miocene of Sindh and Australia.

In the genus *Mopsea*, a dweller on the deep-sea floor, the branching takes place from the intercalcareous or horny part, and there is a fossil Eocene form of it.

In the genus *Melithæa* the outer calcareous parts are porous and corky in appearance.

The sub-family Gorgoninae has a flexible continuous stem which resembles horn more than chitine. The envolving soft parts are well developed, and the polypes may be sunken in it or may project as little warts. There are spicules of carbonate of lime in the soft parts, and sometimes there is some of that mineral in the stem. The stem, marked with grooves on the outside, is formed

* *Corallium rubrum*.

of concentric layers, and they are deposited in the tissues of the deepest portion of the soft parts, one over the other. The nodular spicules are very characteristic, and in some genera they crowd the softer tissues. Some are knobbed at both ends and along their short stem, and the knobs are like cauliflowers; others, with four or five crowns of tubercles, are fusiform; many are club-shaped, with longitudinal crests, or are spiny, and many are scale-shaped and spinose.



ENLARGED SECTION OF STEM OF CORALLIUM RUBRUM (RED CORAL).

The great number of genera of this sub-family may be arranged around certain well-marked ones or types. The genus *Primnoa* has a dendroid stem and long warty or pedunculated knob-like appendages. Each of these contains a polype which is crowded with imbricated scale-shaped spicules. These are movable on their bases. The axis is cylindrical and delicate, and contains some carbonate of lime. They are found in the Atlantic, the Mediterranean, Red Sea, and Pacific Ocean. The genus *Gorgonia* is a type, and about ten others are grouped with it. The stem contains no carbonate of lime, and is corneous. *Gorgonia verrucosa*, of the Mediterranean and English Channel, has a bush-shaped form, or is like an espalier. It branches much, but so as to develop a fan-shaped outline. Some are half an inch and others

one-eighth of an inch in diameter. The polypes are on knob-shaped projections, and have a circular margin.

The nearest ally to *Gorgonia* is the genus *Muricea*, and it has a softer stem, and the polypes are, as it were, bi-lobed. The Western seas of America appear to be its home. Other genera, such as *Plexaura*, have the polypes sunken in the common soft tissue, which is thick and semi-solid. Its species come from the Antilles, the Canaries, and the Pacific. *Leptogorgia*, on the contrary, has a thin, almost membraniform, soft tissue, and the margins of the polypes do not project, and there are no knobs or warts. A flat stem, branching in twos, and forming a plume shape, is characteristic of the genus *Lophogorgia*; and when the polypes, instead of being placed all around the stem and branches, are restricted to longitudinal lines on either side of a median groove, the forms belong to the genus *Pterogorgia*. Other genera have a foliaceous-looking stem, some are in straight sword-shaped masses, as *Xiphogorgia*, and the rest have the branches uniting, so as to form a leafy shape. In *Rhipidogorgia* the fan shape is very decided, and the soft parts have little warty polypes close to the hard tissue. This genus has many species in the Australian, Pacific, and Atlantic seas. In fact, the world-wide distribution of nearly all these genera is very remarkable. Another type

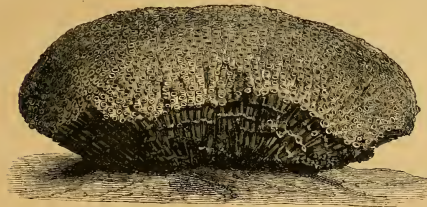
has a large quantity of carbonate of lime in its stem, and it is interesting to note the repetition of external form, in this division, of that noticed amongst the corneous-stemmed forms. It is the genus *Gorgonella*, and it corresponds to the *Leptogorgias* in the last division, but the axis is very calcareous, and *Verucella* has the configuration of the *Gorgonizæ*. One genus, *Juncella*, has a simple, non-branching, straight stem, like a stick, and the polypes project slightly. It has been found in the Mediterranean, off Bahia, and on the east coast of Africa. The last group is that of the *Briaraceæ*, in which the axis, or stem, is no longer dense, solid, and concentric, but may be hollow or a mere mass of spicules. *Briareum* is the typical genus, and *Paragorgia* is its most important ally.

THE FAMILY ALCYONIDÆ.

With the exception of one genus, this great family is characterised by the absence of anything, like a continuous skeleton or supporting dense hard structure. In no case is there an axis, as in the Red Coral and *Gorgonias*, but there is much soft structure, in which isolated calcareous sclerites or spicules are placed, sufficient to detract from a perfect contractility and softness. Hence some are leathery or fleshy. The polypes are fashioned after the *Alcyonarian* type, have eight pinnate tentacles, and their visceral cavity has membranes in it supporting the reproductive elements. The soft tissues, or *cœnosarc*, contain the polypes, whose centres communicate with a common series of minute canals. Many forms increase by budding, some from the base and others from the sides, and thus two sub-families, the *Cornularinæ* and the *Alcyoninæ*,



SEA FAN (*Gorgonia flabellum*).



TUBIPORA MUSICA (ORGAN-PIPE CORAL).

can be established. There are some forms, however, which produce a wall of calcareous spicules and a kind of corallum, and thus a third sub-family, the *Tubiporinæ*, is formed. This is a very exceptional form, and the rest are fixed by their fleshy bases. Where the polypes are in considerable numbers and surrounded by a *cœnosarc*, they extend deeply, and as they are produced by budding they may have their visceral cavities elongate and

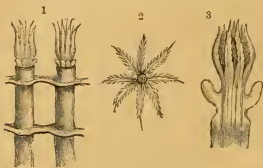
either in the direction of the lower sides or of the whole mass. Some are very retractile.

The Organ-pipe Coral * forms very considerable masses of a deep red colour, and is found in the Red Sea and the Pacific. Its appearance is very familiar to visitors to museums, and it is made up, in the dry and the dead state, of a multitude of small cylindrical tubes placed in rows one over the

* *Tubipora musica*.

other, and separated by a kind of semi-tubular and cellular tissue, which forms layers of considerable extent. Usually the number of tubes is small at the base of a mass, and it increases at each layer of the cellular tissue, so that it is very great at the surface of a large piece. Each tube is made up of a great number of sclerites, nearly united together, so that their original shape cannot be made out, and it is hollow within, and more or less cylindrical. But there are funnel-shaped projections inside, and also incomplete horizontal tabulæ. There are no septa. The tubes are separate, slightly porose, and the new ones spring from the horizontal layers, whose cavities communicate with the larger tubes. The polype fills the upper part of the tube, and its outer derm passes over the edge, or rather is continuous with it, and the sclerites are developed in its midst. There are eight tentacles, with from fifteen to seventeen pinnæ on either side of each, and there are spicules within. The mouth has a slightly raised lip. When the polype is alarmed, the tentacles close, and then the whole is withdrawn into the tube. The lower part of the tube, above the uppermost tabula, is occupied by the gastric cavity, separated above from the stomach by a delicate tissue. The ovaries are in the lower cavity, and the mesenteries, eight in number, are like thin slender cords.

The genus *Tubipora* forms a sub-family of the Alcyonidae, and there are several species of it. Probably it is of great antiquity, for there are things like it in the Devonian rocks.



TUBIPORA MUSICA.

1. Tubes magnified and containing polype. 2. Tentacles of *Tubipora* polype. 3. Polype magnified.

The Alcyoninæ are fleshy and soft, and increase by ova, and also in mass by a process of budding from the sides of the polypes. The buds are enclosed in a very strongly-developed cœnosarc, and the mass may be simple, lobed, or branched. There are two divisions of the sub-family. In the armed or spiculate one, the tissue of the body is thin and soft deeply, but the outer derm is almost consolidated or very leathery, on account of the number of large boat-shaped spiculæ. These resemble those commonly found in the Alcyonaria at the base of the tentacles, but which are small in that position. The extremities of the spicules

project at the surface, and give an echinulate appearance to the individual. In the genus *Nephthya* the derm is a leathery skin, bristling with spicules, and it forms branching lobes ending in projecting tubercles in which are the polypes. The only known species is from the Red Sea. In the genus *Spoggodex* the animal is membranous and flexible, and the polypes are incompletely retractile within the tissue which contains the spicules. An almost cylindrical tube of leathery skin with spiculiferous walls contains the highly retractile polypes of the genus *Paralcyonium* of the Algerian seas, and this is the nearest ally to the *Tubipores*. No less than twelve genera belong to the next division of naked Alcyonians. These have a semi-cartilaginous consistence, and merit the term fleshy, but the density is due to the presence of a multitude of microscopic nodular sclerites. The surface is granular and very spinulose. The genera may be grouped according to the contractility of the polypes; and in the genus *Alcyonium*, which is lobed-shaped or finger-shaped, the contractility is complete. The polypes retreat within a dense cœnosarc; they increase by budding. One of the species* has a singular hand-shape, and is called Dead Man's Fingers on the English coasts. The polypes are large, very numerous, and occupy the greater part of the surface, and the colour may be white, or grey, or orange. They are fixed on to stones and shells, and the ugly mass of slimy-looking substance if placed in pure sea-water gradually sends forth its beautiful polypes. The genus *Ammonothea* is a branching form, with spicules on the branches, and it probably should be placed with the other division. Its polypes are semi-retractile.

The polypes of the last genus to be mentioned, *Xenia*, from the Red Sea and Fijis, are non-retractile, and are on a fasciculate and fleshy stem.

Amongst the genera of the sub-family, the Cornularinæ, are some simple or isolated forms, or they may be united by a kind of prolonged base or stolon, out of which they have been formed by budding.

The simple kinds have a tubular shape, and the polype is retractile, and they belong to the

* *Alcyonium digitatum*.

genus *Haimea*. Compound kinds may have root-shaped stolons, and the polypes may be tubular. In some of these, the *Cornulariæ*, for instance, the polypes are completely drawn in, and are retractile, and the stolons fix on to all kinds of substances. There are no spicules, and the bottom of the visceral cavity communicates with the buds by minute canals. They are Mediterranean species. The *Clavulariæ* resemble these, but contain spicules, and inhabit the shores of Vanikoro. Some species without retractile polypes, but otherwise like the *Cornulariæ*, are found in the Moluccas, the Bay of Naples, and coast of Norway. They belong to the genus *Rhizoxenia*. Some wart-shaped polypes, hardly higher than the stolons which bear them, characterise the *Sarcodictyons* of the Scottish coasts. The colour of the stolon in one species is red, and the polypes are yellow, and in another the tint is yellow-brown.

The next division refers to species which have a membranous basal expansion, and not stolons, and in the genus *Anthelia* the polypes are very projecting, and when it contracts the tentacles come within the base.*

The ancient forms of the Anthozoa have been slightly alluded to in the past pages, and it is necessary to add that the groups *Aporosa* and *Perforata* were faintly foreshadowed in the Palæozoic ages, and began to be of importance in the early Secondary times. The *Aporosa* appear to have been the most numerous. The reefs of the Oolitic age had a great fauna, and the Chalk contains relics of a fauna which resembled that of the deep seas of the present time. Many genera of Tertiary corals are now existing, and a few species also. The group *Rugosa* is a very difficult one to define, and it flourished during the Palæozoic age. In many forms the septa are so close together, and the space between them is so restricted, that it is doubtful whether mesenteries and ovarian apparatus could have existed there. In some there is a groove, or more than one, in the place of a principal septum; and in several genera of compound kind the columella and surrounding septa almost recall the *Stylasters*. Some of the *Rugosa* may have been corals having soft parts, something like those now existing, but others were probably *Alcyonarians*, and not a few must be classified near the *Millepores*.

CLASSIFICATION.

CLASS.—ANTHOZOA.

ORDER.—ZOANTHARIA.

Sub-order.—Madreporaria.

Group.—Aporosa.

Families.—*Turbinolidæ*, *Oculinidæ*, *Astræidæ*, *Stylinaceæ*, *Astræinæ*, *Fungidæ*.

Sub-family.—Stylophorinæ.

Group.—Perforata.

Families.—*Eupsamminæ*, *Poritidæ*.

Group.—Rugosa.

Sub-order.—Antipatharia.

Sub-order.—Actinaria.

Families.—*Actinidæ*, *Cerianthidæ*.

ORDER.—ALCYONARIA.

Families.—*Helioporidæ*, *Pennatulidæ*, *Gorgonidæ*, *Alcyonidæ*.

P. MARTIN DUNCAN.

THE GROUP SPONGE.

The Turkey Bath Sponge as a Type—Its Structure and Embryology—Its Mode of Life—Specific Distinction and Existing Distribution—Sponge-farming—Forms and Colour of Sponges—The Individuality Question—Different Types of Canal System—The Three Primary Layers—The Skeleton—Spicule Forms—Embryological Development—Affinities of the Sponges—Their Classification—General Characters of Existing Families—Their Distribution in Space and Time.

THE Sponges are a numerous, diverse, and yet compact, group of animals, manifesting, amidst a remarkable diversity of minor characters, a fundamental similarity by which they are united closely together, and separated from all the rest of the animal kingdom. In a word, they are Metazoa, or multicellular animals, in which the endodermal layer characteristically consists, partly or wholly, of flagellated collared cells.

A clear idea of the nature of a Sponge will be most readily obtained from a description of a single well-selected example, and none is better suited for the purpose than the common Bath Sponge. The object which is usually denoted by that name is but the skeletal remains of the animal—a delicate elastic network, which so intimately pervades every part of the living organism that, after all the other tissues are removed, it still presents a faithful model of the general form and structure of the whole.

There are several kinds of Bath Sponge, but the one to which we shall restrict our attention is the fine Turkey Sponge (*Euspongia officinalis*), of which there are several well-marked varieties, differing greatly in form. Some are cup-shaped masses, with thick walls, or more or less globular clumps; others flat, somewhat ear-shaped plates; and others, again, encrusting patches from which small tubes grow upwards. The colour of the exterior is usually some tint of brown, varying from yellowish-grey to black; within it is of a lighter shade, varying from greyish-yellow to colourless, but in one variety it is rusty red.

A thin skin covers the whole surface of the Sponge, rising, tent-like, about the projecting ends of the chief fibres of the skeleton. These projecting ends can readily be seen with a lens on an unused skeleton of a Bath Sponge.

In various places, irregularly distributed, the skin is perforated by circular holes known as oscula, which can be opened or closed by the movements of a delicate iris-like membrane which forms their margin. The oscula are the terminal openings of wide tubes which descend into the interior of the Sponge, repeatedly branching like the roots of a tree in their course till they become too small to be followed by the unassisted eye. They are known as the excurrent canals; and the tubular spaces in the skeleton corresponding to them, as well as the general position of the oscules, are clearly visible in the Sponge of domestic use. Besides the oscules, large circular openings, characterised by the absence of the iris-like margin, are sometimes, but by no means always, present. They lead into wide canals which are usually tenanted by some large marine worm (*e.g.*, *Nereis costae*), which was regarded by Peyssonel as "the essential animal and sole fabricant of the Sponge, all the rest being merely a nidus or excretion!"

On examining the surface of the Sponge with a strong lens, there will be seen over those areas devoid of oscules a number of thread-like ridges descending radiately down the tent-like elevations of the skin, branching as they go, and united laterally by similar but transverse ridges into an irregular network with polygonal meshes. A number of round apertures, called pores, are situated in these meshes, and give them a sieve-like appearance (Fig. 2). The pores lead into a roomy space, the subdermal cavity, which spreads beneath the skin; from it canals descend direct into the interior of the Sponge, and sooner or later become branched; these are known as the incurrent canals (Fig. 1).

Thus the Sponge consists of a fleshy mass, supported by a network of elastic fibres, invested with a skin, and traversed by two sets of canals—excurrent canals, each opening by a single oscule to the exterior, and incurrent canals, which communicate with the exterior by cribriform pore areas. Nearly this much, if we except the distinction of the canals into two kinds, was well known at a very early date, probably from the time of Aristotle, two thousand years ago; but so little does the structure, so far ascertained, resemble that of any other kind of animal, and so little light does it throw on the real nature of the organism, that the earlier naturalists were unable to infer from it

certainly even whether they should regard the Sponge as an animal or a plant. Some, like Lamarek, supplied what was wanting by a free use of the imagination, and, supposing that the oscules were the mouths of cells occupied by little polypes, which constantly succeeded in evading observation, were enabled to class the Sponges with the Alcyonia; while some zoologists, who knew little about plants, handed over an organism which they did not understand to the care of the botanists. Nor was much help to be had from an examination of the Sponge in a living state; for, beyond mere growth, it presents no obvious signs of life. Marsigli was the first, in 1711, to observe the dilatation and contraction of the oscular openings, and afterwards Ellis asserted that he saw currents of water flow into them as well as out — a most exceptional occurrence — and thence inferred that the oscules were mouths by which the Sponge sucks in and squirts out water. In all this there was no progress, and it is to Robert Grant that we are indebted for the fundamental discovery which dispersed the mystery that had surrounded the physiology of the Sponge since the early time of Aristotle. His discovery consisted in the fact that he plainly witnessed currents of water containing floating particles of food flowing through the pores of the skin into the Sponge, and, at the same time, other currents of water, burdened with fecal residues, flowing out of the oscules from the excurrent tubes. By this flow of water through it the life of the Sponge is manifested and maintained. The following is Grant's own account of his earliest observations:—

“In the month of November last, I therefore put a small branch of the *Spongia coadita*, with some sea-water, into a watch-glass, under the microscope, and, on reflecting the light of a candle

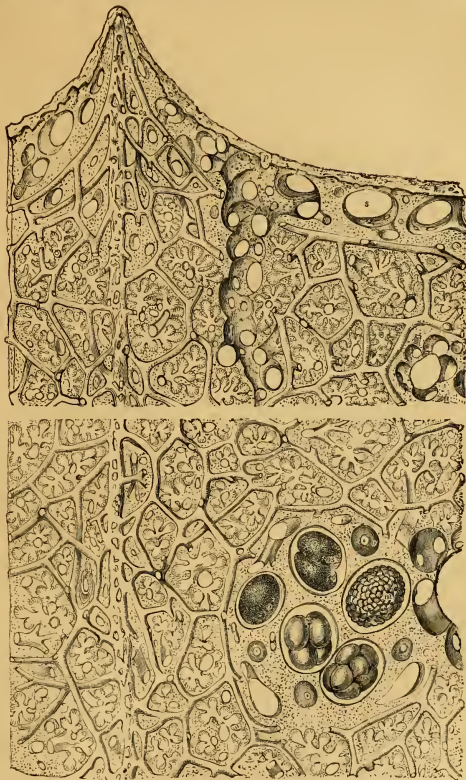


Fig. 1.—SECTION OF TURKEY BATH SPONGE. (After Schulze.)

p, Pore; s, subdermal cavity; i, incurrent canal; f, flagellated chamber; cl, chief fibre of the skeleton; c2, connecting fibres; o, ova in various stages of growth; os, ovum segmenting; m, morum. ($\times 40$.)

up through the fluid, I soon perceived that there was some intestine motion in the opaque particles floating through the water. On moving the watch-glass, so as to bring one of the apertures on the side of the Sponge fully into view, I beheld, for the first time, the splendid spectacle of this living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around. The beauty and novelty of such a scene in the animal kingdom long arrested my attention; but, after twenty-five minutes of constant observation, I was obliged to withdraw my eye from fatigue, without having seen the torrent for one instant change its direction, or diminish, in the slightest degree, the rapidity of its course. I continued to watch the same orifice, at short intervals, for five hours, sometimes observing it for a quarter of an hour at a time, but still the stream rolled on with a constant and equal velocity. About the end of this time, however, I observed the current become perceptibly languid, the opaque flocculi of feculent matter, which were thrown out with so much impetuosity at the beginning, were now propelled to a shorter distance from the orifice, and fell to

the bottom of the fluid within the sphere of vision; and, in one hour more, the current had entirely ceased."

Grant afterwards observed the currents of water entering the pores, and illustrated his observations by a drawing, of which Fig. 3 is a facsimile copy. He then sought for the cause of the water-streaming, and rightly conjectured that it must be due to ciliary action, but sharp-sighted as

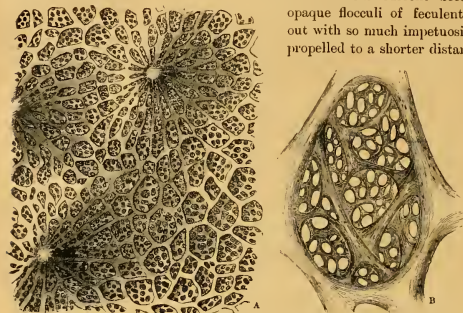


Fig. 2.—PORIFEROUS SURFACE OF A SPONGE (*Spongia avara*. After Schulze.)
A, Magnified 10 diameters; B, a single pore, \times 60 diameters.

he was he failed to find the cilia, though he especially looked for them. They were subsequently discovered, however, by Dobie, Bowerbank, and Carter, and the last showed that the cells bearing the cilia, or flagella, as these whip-like filaments are termed when each cell bears only one of them, are usually arranged in spherical chambers, to which he gave the name of ampullaceous sacs, but which are now more generally known as flagellated chambers. Finally, F. E. Schulze, in his faithful and beautiful illustrations of Sponge-structure, showed exactly how these flagellated chambers are brought into relation with the excurrent and incurrent canals; and this brings us back to the Bath Sponge. In this, as in most other Sponges, the terminal branches of the excurrent canals dilate at their ends into flagellated chambers (Fig. 4, c), about 0.001 inch in diameter, which are clustered about the penultimate branches of the excurrent canals like grapes in a bunch. The terminal branches of the incurrent canals apply themselves to the round ends of the chambers and open into them by one or usually more small circular pores. The flagellated cells are arranged in a single layer on the walls of the chamber, and rapidly lashing the water in one direction drive it into the excurrent canals; the multitudinous little streams so produced flow together in the larger excurrent tubes, and are finally discharged in a powerful current through the oscules. The water driven out of the chambers is replaced by an inflow from the incurrent tubes, and the loss from these is made good by the minute currents which stream through the dermal pores. These entering currents bear with them minute proteinaceous particles, such as minute infusoria, diatoms, and minute algae; they also contain oxygen in solution; the outflowing currents carry away fecal residues, and also the excreta urea and carbonic acid. The solid particles of food are ingested by the cells lining the excurrent canals, and particularly by the flagellated cells. This can most readily be proved by

feeding any kind of Sponge with carmine, killing it with osmic acid, hardening in alcohol, and then cutting from it thin slices for examination under a high power of the microscope. The flagellated chambers will then be seen clearly marked out from the rest of the Sponge by the abundant presence of the ingested colouring matter. So close a resemblance exists in all other respects between these cells and certain flagellated infusoria, that in all probability they also feed in the same way, and we may consequently describe the feeding of the Sponge-cell after that of the infusorian. The flagellum, then, of each Sponge-cell creates currents in the water towards itself, and the floating particles borne along with these come in contact with, and adhere to, a delicate film which surrounds the long neck of the cell like a collar (Fig. 5); the protoplasm of the collar is in a state of active circulation, streaming up one side and down the other like an endless band; the adherent food particles are thus carried by it to its base, where they come in contact with the neck, sink into its substance, and find their way into the basal part of the cell. A little drop of water is included with them, and thus the flagellated cells not only eat but drink; the food is next digested, and when all the goodness is got out of it, the fecal residue is extruded by an extemporised aperture from the cell, and forthwith carried out of the Sponge by the outflowing currents. The circulation of the collar must expose a large and constantly changing surface to the surrounding water, and so allow of the absorption of oxygen and the escape of carbonic acid; this is one way in which the cell breathes. The proteinaceous compounds of the cell unite with oxygen, and in so doing liberate energy, which is partly expended in maintaining the movements of the flagellum and collar. The final products of the union of the protoplasm with oxygen are water, carbonic acid, and urea—the second useless and therefore in the way, the last a deadly poison; if the life of the cell is to be maintained, the carbonic acid and urea, together with the excess of water, must be got rid of or excreted. This is accomplished through the agency of one or more contractile vesicles, which alternately expand and contract, a slow expansion, during which water containing the other excreta accumulates in them, being followed by a rapid contraction by which it is expelled. Thus the flagellated cells eat, drink, breath, and excrete. They also grow and multiply in number; the excess of food which is not expended in producing energy leads to increase in size or growth, and this, when it passes a limit, gives place to division or fission, by which the cells are multiplied: the division may be either longitudinal or transverse; in the first case it increases the number of cells in the flagellated chamber; in the second one of the

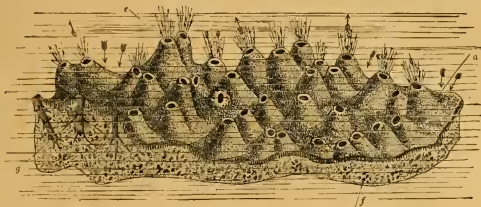


Fig. 3.—FAC-SIMILE OF GRANT'S FIRST FIGURE.

a, Pores; c, oscule; f, ova; g, embryo entering excurrent canals. The outward arrows show water escaping from oscules; the inward ones water entering the pores.



Fig. 4.—FLAGELLATED CHAMBERS (c) OF TURKEY BATH SPONGE IN CONNECTION WITH THE EXCURRENT (E) AND INCURRENT (I) CANALS. (After Schultze.)

cells possesses an amœba-like character, and wanders into the main tissue of the Sponge, to be immediately described along with its other histological constituents.

The Sponge, like all other Metazoa, is ultimately resolvable into cells; and of these tissues are built up, which are arranged in three definite layers—the ectoderm, endoderm, and mesoderm. The ectoderm is a layer of flattened polygonal cells (Fig. 6, ec), which cover the whole exterior of

the Sponge, and line the incurrent canals throughout; the margins of the cells are usually invisible, but can be readily developed by treatment with nitrate of silver. The endoderm, or inner layer, lines the excurrent canals, and has the same structure as the ectoderm, except in the flagellated chambers, *i.e.*, the expanded ends of the smallest excurrent canals, where it

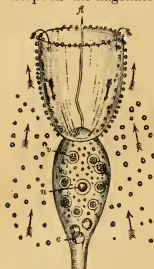


Fig. 5.—FLAGELLATE COL-
LARED INFUSORIAN FEED-
ING, $\times 2,000$ dia. (After
Saville Kent.)

The arrows show the direction of the current induced by the rotatory motion of the flagellum (*f*), *e*, food vacuole; *n*, nucleus; *c*, contracting vesicle.

forms a single layer of flagellated cells (Fig. 6, *en*). These consist of a spherical body of protoplasm, granular within, but firmer and clearer externally; containing a nucleus, and one or more contractile vesicles; one end is seated on the wall of the chamber, the other is prolonged into its cavity as a long neck of clearer hyaline protoplasm; around its margin the end of the neck extends into an immeasurably thin cylindrical or conical collar, while from its centre is produced a long slender flagellum.

The tissue between the two preceding layers is the mesoderm (Fig. 4); it consists chiefly of a clear, greyish, jelly-like matrix containing irregularly stellate granular nucleated corpuscles, united by branching processes into an irregular network. In the neighbourhood of the flagellated chambers the definite outline of the corpuscles disappears, and they merge together, crowding the matrix with minute granules, amidst which the nucleus remains unchanged. This gelatinous connective tissue is very similar to that forming the disc of Jelly-fish; it originates in cells, which first become confluent, as about the flagellated chambers, and then change about their confluent margins into the jelly-like matrix, their central part, with the nucleus, remaining as the stellate corpuscle. In certain places, as around the oscular openings, and in the circular diaphragms, which at intervals constrict the main water canals, the corpuscles present a fusiform shape, acquire more or less distinct walls, and serve the function of muscle

fibres. They present the same shape and appearances in other places, as parallel to the skeletal fibres, and directed lengthwise in the walls of the main canals but here their function is that of fibrous connective tissue. Besides these cells, which, though contractile, are not locomotive, there are other amœbiform cells which wander in the tissue, and frequently contain large granules looking like fat or starch, serving no doubt as food reserves.

The skeleton, which is a product of the mesoderm, consists of a network of spongin fibres (Fig. 1), the substance of which in chemical composition most closely resembles silk, both compounds being regarded by chemists as horny matter. The fibres may be distinguished as chief fibres and connecting fibres; the former, radiately arranged, project at right angles to the Sponge-surface; the latter form a network transversely uniting the chief fibres together. Both have the same essential structure, consisting of a thick, transparent, concentrically-layered wall, and a soft granular axial thread; but the larger chief fibres contain in addition foreign particles, such as sand-grains, sponge-spicules, and fragments of shell. They are formed as a secretion by modified cells of the mesoderm; and the chief fibres obtain their included particles by embedding at their soft terminations, the foreign material which lies plentifully strewn over the skin.

Reproduction (Fig. 1).—The ova and spermatozoa are found in the mesoderm. The former commence existence as cells remarkably similar to the amœbiform corpuscles of the connective tissue, being chiefly distinguished by their large bladder-like nucleus and its large round nucleolus; as they increase in size yolk-granules make their appearance, and at length the egg assumes a regular ovoid form. It is noteworthy that the eggs in *Euspongia* are not, as in other Sponges, scattered irregularly through the mesoderm, but occur in groups of ten to twenty in number near the large excurrent canals embedded in a matrix of connective tissue, which is more or less separated from the rest of the

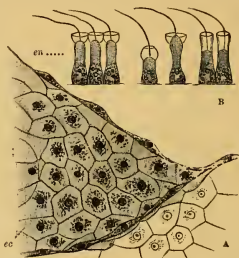


Fig. 6.—ECTODERM, AND DIFFERENT FORMS OF ENDODERMIC CELLS FROM SCYANDRA RAPHANUS. (After Schulze.)

A, *ec*, ectoderm; B, *en*, endoderm cells, $\times 500$.

body by surrounding lacunar spaces. This seems to be an approximation to a rudimentary ovary. The eggs come to maturity at all times of the year. The spermatozoa (Fig. 7) occur in globular clusters, known as sperm-balls, each the product of a single cell; they are strewn through the Sponge and not collected in special areas.

Ova and spermatozoa are never developed, or at all events have not been observed, in the same individual, so that in the Bath Sponge, as in some other Sponges, though by no means in all, the sexes are distinct.

Development.—The entrance of the spermatozoon into the ovum, which constitutes the essential act of fertilisation, has not yet been certainly observed in this or any other known Sponge, but the resulting changes have been seen and carefully traced up to a certain stage. The ovum first divides into two similar cells, each of these again subdivides, and four similar cells result; subdivision again takes place and eight cells result, and this process of segmentation is continued till at length a spherical cluster of similar cells, the well-known mulberry-mass, or *morula*, is formed (Fig. 1). The morula then becomes differentiated into an inner mass of connective tissue cells, and an outer layer of small cylindrical cells, coloured by pigment granules, and each furnished with a flagellum. The flagellated embryo extricates itself from the parent Sponge, and whirls rapidly about in the surrounding water. It has a compressed oval form, and resembles the planula of some corals. Its further history is unknown.

Besides this natural mode of propagation the Bath Sponge can be multiplied, like a plant, by artificial cuttings. The demand in the arts for the Bath Sponge being in excess of the supply, attention has been directed to its cultivation, and with great success. The Sponge is cut into pieces, about one inch cube, care being taken to preserve as much of the skin and to squeeze out as little of the flesh as possible; the cuttings are then skewered on a strip of cane, and fastened into a wooden frame, constructed to preserve them from the access of mud and excess of light; they are then sunk in the sea at a depth of about five to seven yards. In about seven years' time a crop of fine regularly globular Sponges is ready for the market. A capitalist or a company is now all that is required to make Sponge farming a profitable pursuit.

Classification.—The species of Sponge in common use are three:—*Euspongia officinalis* (Lin.), the fine Turkey or Levant Sponge, just described; *Euspongia zimocca* (Schmidt), the hard Zimocca Sponge; and *Hippospongia equina* (Schmidt), the Horse Sponge, or common Bath Sponge. The genus *Euspongia* is distinguished by the regular development of the skeletal network throughout the body, its narrow meshes, scarcely or not at all visible to the naked eye, and the regularly radiate arrangement of its chief fibres; *Hippospongia* is distinguished by the thinness of its fibres and the labyrinthine character of the skeleton beneath the skin, due to its being closely traversed by numerous winding canals of about one-fifth to two-fifths of an inch in width. As a consequence its chief fibres have no regular radiate arrangement.

The species of *Euspongia* are distinguished as follows:—In *E. officinalis* the chief fibres are of different thicknesses, irregularly swollen at intervals, and without exception cored by sand-grains; in *E. zimocca* the chief fibres are thinner, more regular, and almost free from sand; in *E. officinalis* again the uniting fibres are soft, thin, and elastic; in *E. zimocca* denser and thicker—it is to this difference that the latter Sponge owes its characteristic hardness. Finally, the colour of the skeleton in *E. officinalis* is a light clear yellow, in *E. zimocca* a dark brown yellow. The common Bath Sponge (*H. equina*) has almost always a thick cake-like form, but its specific characters are not yet further defined.

Distribution.—*Euspongia officinalis* is found at various parts of the Mediterranean coast, as also are the other two species of Bath Sponge. A species not to be distinguished from it occurs also in the Caribbean Sea about the shores of the West Indian Islands, and associated with it are two



Fig. 7.—SPERMATOCOA (*Haliarsa lobularis*). [After Schulze.]

A, Separate spermatozoa, $\times 800$; B, sperm ball, $\times 500$.

other species, the "yellow" and "hard-head" Sponges of the American shores, resembling *E. zimocca*; and the "wool" Sponge, which appears to be one or perhaps two species of the Hippo-spongia, *H. gossypina*, and *H. meandriformis*, the "velvet" Sponge.

GENERAL CHARACTERS OF THE SPONGE.

In form and size Sponges vary greatly: some are no larger than a pin's head, others as much as four feet in height and breadth, while some attain a length of over six feet. In form they are massive; incrusting, sessile, or stalked; globular, branched, tree-like, with the branches free or united laterally into a network; lamellar, irregularly or fan-shaped; tubular, vasisform, or labyrinthic, many of the forms presenting a close parallelism to those of Corals. In some the form is constant and characteristic, as in the fairy-like Venus-basket (*Enplectella*, Fig. 9, A); the glass-rope Sponge with its cylindrical body (*Hyalonema*, Fig. 9, B); the open Flower-basket Sponge (*Dactylocalyx*, Fig. 9, E); or the great Neptune's Drinking Cup (*Poterion*, Fig. 9, C); but usually it is very variable; and since the same species may assume different forms, and the same form be common to different species, external shape is of very slight value in classification. The different forms can be derived from each other in many cases by quite easy gradations. Thus from a massive spreading Sponge may grow up finger-like extensions, and these, by branching, give rise to a tree-like form. By the subsequent union of the branches a net-like or clathrous stock results; or the finger-like elevations may widen into a lamella which, broadening as it grows, becomes fan-shaped; growing more rapidly on one face than the other, the fan becomes curved, and as the curvature increases the approximated edges at length touch and join together, producing a cup-like or vase-like form, the origin of which remains clearly indicated by a hole near the base, where the sides of the fan failed to reach, and still remain apart.

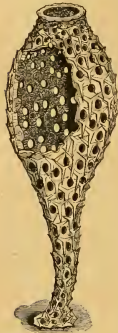


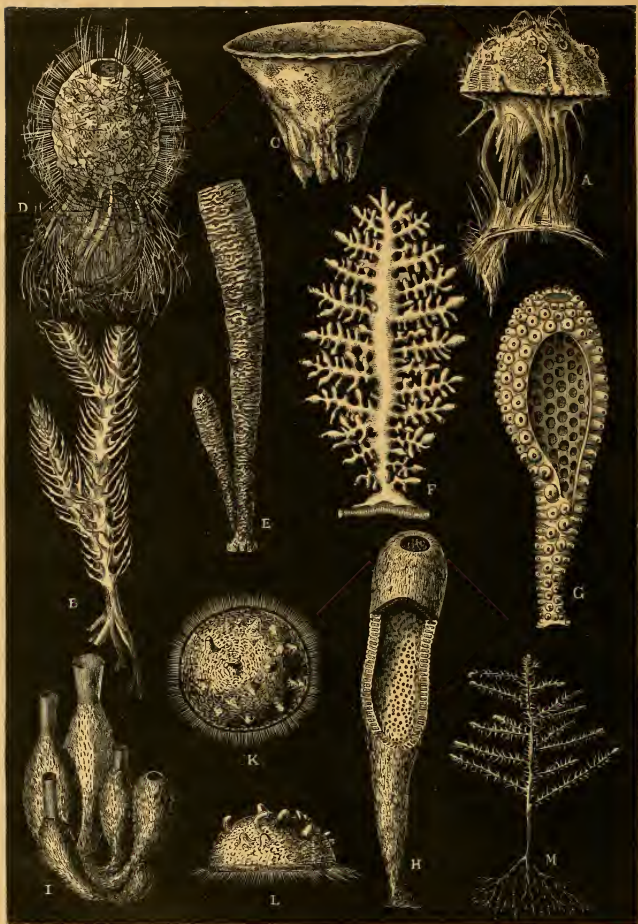
Fig. 8. — ASCETTA
PRIMORDIALIS,
× 50 dia. (After
Haeckel.)

The mass which we speak of as the Sponge may consist of a single individual or several, just as a Coral may be single or compound, but it is not so easy in the case of the Sponge to determine what constitutes an individual. Usually the osculum is taken as the characteristic mark of a "person," but in some Sponges the osculum is absent (lipostomism) and the

excurrent canal opens by the pores. In this case the excurrent canal must be regarded as indicating the individual, but again even this may disappear (lipogastrism), and then the question of individuality becomes as puzzling as it would be in a Coral which had lost all its polypes and consisted only of coenosarc; in this case we must regard as an individual the whole Sponge mass. The colours of Sponges, which are very various, are usually due to the presence of pigment granules embedded either in the endosarc of the flagellated cells, or in the mesodermic cells; usually of the skin only, but sometimes of the whole body. The various tints range through the whole octave of colour, the commonest perhaps being various shades of yellow and brown; grass-green and orange-red are frequent; rose red, faint lilac, deep carmine, sky-blue, indigo, black, are also not rarely met with, as well as all the colours of flowers and of the leaf from the bud to the fall. Sometimes the colour of the same species differs in different localities, as in *Ascetta clathrus*, which, though usually grey, is sometimes sulphur-yellow or vermilion-red. Many Sponges are white as snow, and, for the same reason, their minute colourless transparent spicules scatter the incident rays of light, just as the tangled crystals of a snow-flake do. Occasionally the colour of the Sponge is accidental, as when it depends on that of ingested food particles, or of parasitic algae.

Those pigments which belong to the chlorophyll group no doubt play the same part here as they do in plants, protecting the protoplasm (which is able to build itself up from carbonic acid, water, and ammonia under the action of sunlight) from the destructive effect of the violet rays; the parasitic algae are probably of great service to the Sponge, both in absorbing its excreted carbonic acid, and liberating oxygen for its use.

The Canal System.—Although the type of canal system described in Euspongia is by far the



SPONGES.

A. *Thenea wallichii*—a Choristid Tetractinellid (After Thomson); B. *Chondrocladia virgata*—a Desmaciine Monaxonid (After Thomson); C. *Askonema setabaleuse*—a Lyssakine Hexactinellid (After Thomson); D. *Rossella velata*—a Lyssakine Hexactinellid (After Thomson); E. *Luffaria archeri*—a Ceratine Ceroesporgia (After Higgin); F. *Ascandra sertularia*—an Ascon Calcisponge (After Haeckel); G. *Sycetta primitiva*—a Sycon Calcisponge (After Haeckel); H. *Sycortis levigata*—a Sycon Calcisponge (After Haeckel); I. *Sycometra ciliata*—a Sycon Calcisponge (After Haeckel); J. *Trichostemma hemisphericum*—a Suberite Monaxonid (After G. O. Sars); K. *Cladorhiza abyssicola*—a Desmaciine Monaxonid (After G. O. Sars). Figs. F, G, I, are magnified; all the rest reduced in size.

most widely distributed amongst the Sponges, it is, at the same time, the most complicated. In its simplest expression, the canal system is found amongst the lower members of the Calcispongiae, as in the little *Ascetta blanca* (Fig. 8), discovered by Mickluch Maclay. This is simply an oval sac, with a large internal cavity, and very thin walls, opening at one end by an osculum, attached at the other, and perforated all over by numerous short pore canals. The endoderm consists entirely of flagellated cells, so that these line the whole interior, and driving the water out at the mouth, cause an influx through the pores, which are mere fluctuating apertures, with no constancy in position. There are here no true incurrent canals, and the whole Sponge might be compared to a magnified flagellated chamber with a surrounding layer of mesoderm and ectoderm. Haeckel regards it as similar to a

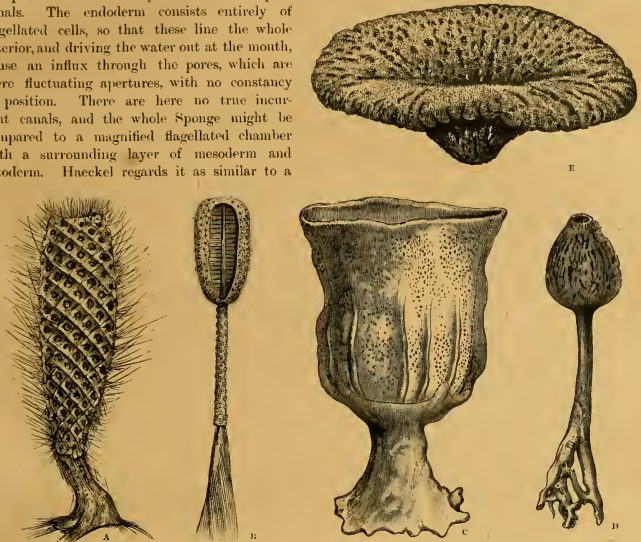


Fig. 9.—A, *EUPLECTELLA SUBEREA* (After Thomson); B, *HYALONEMA SIEBOLDII* (After Schulze); C, *POTERION* (After Harting); D, *SIPHONIA PYRIFORMIS* (After Sowerby); E, *DACTYLOCALYX STUEHBURII* (After Sollas).

single Hydrozoon. Neglecting the spicules which are embedded in its mesoderm, *Ascetta* might be regarded as an embodiment of just so much as is common to all the Sponges, a concrete definition of the group.

From this simple stage the more complicated appear to arise in two ways; in one, which is characteristic of the small group of Sycones, buds, repeating in every way the structure of the parent, sprout out at right angles from the wall of an Ascon such as *Ascetta*; to the central cavity of these the flagellated cells become restricted, those of the original Ascon becoming converted into polygonal pavement cells; the central cavities of the buds remain in free communication with that of the parent. The latter is now the excurrent canal, the former the flagellated endings or branches of it. (Plate 71, Fig. G.) In more integrated forms the buds grow close together, touch, and unite along the lines of contact, the narrow canal-like interspaces left between them serving for the conduct of water to the pores, and constituting an incurrent canal system. (Plate 71, Figs. H, I.)

Precisely how complication ensues in the other case, which is that of the great majority of Sponges, is not quite so clear; but it would appear that from the endoderm of a sac resembling an Ascon hollow buds are formed, which project into the mesoderm. These are the flagellated chambers.

A folding of the entire wall of the Sponge follows (this is an irregular form of budding), and converts the originally simple central cavity into smaller canal-like spaces, in other words, it becomes a branched excurrent canal system; the interspaces between the folds outside the Sponge wall become the incurrent canal system.

Histology.—The ectoderm appears to maintain its pavement epithelial character very constantly, but sometimes its cells become flagellated, as in *Halysarca* and *Plakina*. The endoderm undergoes no great variation. The mesoderm, on the contrary, differs a good deal in different Sponges; in many it consists, as in *Euspongia*, of a clear jelly-like matrix, embedding branched granular corpuscles; in others it becomes densely charged with minute granules, maintaining throughout the character it presents locally about the flagellated chambers of *Euspongia*, while in some it appears to consist of separately-outlined granular cells. The clear granules, which fill some of the wandering amœbiform cells, are, in some cases, certainly starch. The fusiform cells of the mesoderm are often abundantly developed, and sometimes form a thick layer beneath the skin, having the appearance of fibrous connective tissue, but where the main water-canals pass through it, this layer is modified to form around each of them a distinct sphinctral muscle.

The Skeleton.—The character of the skeleton is wonderfully diverse, and since it is fairly constant within each species it affords us the best means of classification. Some Sponges, such as *Halysarca*, are entirely destitute of a skeleton, others (Lithistids) are possessed of one of stony hardness, which no one would think of applying to skin except as a counter irritant. The skeleton may consist of a network of horny fibres, the axis of which is either filled merely with soft granular matter, or includes also foreign bodies, often to such an extent as to convert the fibre into a veritable rope of sand; or, instead of foreign bodies, a core of proper spicules, *i.e.*, spicules produced by the Sponge itself, may be present; and the spicules may increase in number, and the horny matter diminish in quantity to such an extent, that the fibre comes to consist only of spicules. The skeleton frequently consists wholly of spicules, but these are far from being always arranged in a fibrous form. The spicules, which are of most diverse forms, are composed of an organic basis (spiculin), densely impregnated or chemically combined with a mineral salt—carbonate of lime in the case of calcareous spicules, silica in that of silicious spicules. This distinction in mineral composition was discovered by Robert Grant. The spicule usually consists of a clear glassy wall, concentrically-layered, enclosing a soft thin axial thread.

It will be convenient to state here that according to the character of their skeleton, the Sponges may be divided into the following four orders:—

Myxospongiae.^{*}—Soft Sponges, skeleton absent.

Calcispongiae.—Skeleton consists of calcareous spicules, never united to form a fibre.

Silicispongiae.—Skeleton characterised by silicious spicules, which may or may not be united into a fibrous skeleton.

Cerospongiae.—Skeleton consists of a network of horny fibres, sometimes including foreign particles, but never proper spicules.

The simplest form of spicule is needle-shaped (acerate), pointed at both ends (Fig. 10, *a*). It grows lengthwise from the middle along a single axis in the direction of the ends; it is thus uni-axial but bi-radiate. Supposing it to cease to increase in length at one end, it becomes an acuate spicule (Fig. 10, *b*), still bi-radiate, but the radii of unequal length; if one radius does not develop at all and is represented only by a globular enlargement, a pin-headed acuate results (Fig. 10, *c*), which is both uni-axial and uni-radiate. If a third ray grows out from the side of the acerate spicule, a tri-radiate but bi-axial spicule is the result (*d*); should all three rays diverge, so that no two are in the same straight line, we have the tri-radiate and also tri-axial form (*e*) so characteristic of the *Calcispongiae*, though by no means confined to them, since it occurs normally in many of the *Silicispongiae*, *e.g.*, the *Plakiniæ*, *Plectronelliæ*, and *Sphinctrilla*, and, as a variation, common, but abnormal, in a great number of other instances. If a fourth branch or ray is produced from the centre, not in the same straight line as any of the others, a quadri-radiate (also quadri-axial) form appears, and this characterises the sub-order *Tetractinellidæ*, though it appears also in Sponges belonging to other groups. The four rays may remain of the same value (*f*), and be disposed without any ascertained relation to the form of the Sponge and its canal system (*Pachastrellidæ*), or one ray may become distinguished from

^{*} Greek, *myxa*, slime.

the rest by excess or defect of development, as the shaft (*g* to *i*), the other three remaining similar to each other being known as the rays or arms. The shaft usually takes a radiate direction in the Sponge, at right angles to the surface, with which the rays, on the contrary, lie more or less parallel; the point of the shaft is directed inwards towards the centre of the Sponge, the head or rayed end outwards. The rays may grow backwards, recurved, giving the spicule a grapnel-like form (*g*), or forwards, fork-like, or outwards at right angles to the shaft; they may remain simple, or bifurcate once (*h*), or more rarely, twice, or even trifurcate, as in a few recent and some fossil forms; finally, they may broaden out in the surface of the Sponge into thin lobate expansions (*i*), and these may become confluent in a circular disc (*j*), in which, however, the tri-radiate origin can still be traced by the



Fig. 10.—VARIOUS FORMS OF SPONGE SPICULES. (After Eowerbank, Zittel, and others.)

form of the axial thread. Returning to the quadri-radiate form, in which the rays are all similar (*f*), another series of changes may result by the ends of the rays becoming branched (*l*), and closely interlocking with those of their nearest neighbours. In this way the firm stony network characteristic of the Lithistids is produced (*k*). These branched spicules may be traced through various modifications till their quadri-radiate form remains no longer recognisable (*m*).

Another group of forms originates in growth in six directions from a common centre along three axes at right angles to each other. The sex-radiate spicule so produced is characteristic of the Hexactinellidæ (*n*). One by one the rays of this form may be suppressed (*o*), so that mingled together in the same Sponge sex-, quinqu-, quadri-, tri-, and bi-radiate spicules may be found, the bi-radiate or acerates (*p*) often still showing signs of their sex-radiate derivation by the cross-like form of the axial-thread in the middle of the spicule.

By suppression of the distal ray of the sex-radiate type, nail-like spicules arise (*q*), the shaft being stuck in the substance of the Sponge, and the four rays spread out in the skin, forming, with the similar rays of adjacent spicules, a square meshed dermal network. The shaft of such a spicule may become greatly elongated (*r*), and then it often serves with others for anchoring or supporting the Sponge in the slimy ooze of the sea floor on which it lives. If the four rays of such a spicule become recurved and much reduced in size, we have a grapnel-headed anchoring spicule (*s*), such as those which compose the twisted wisp-like bundle of the glass-rope Sponge (*Hyalonema*), and which, measuring eighteen inches in length, are probably the largest spicules known.

If growth from a centre takes place radiately in a large number of directions, a stellate spicule (*t, u*) results; fine examples of this are known in *Tethya*. By growth along a constantly changing axis various curved forms are produced (*v*).

Besides the foregoing large spicules, which, as a rule, form the chief skeleton of the Sponge, other much smaller ones exist (Fig. 11), which, because they are seldom united into a coherent skeleton, but occur dispersed throughout the mesoderm, have been termed flesh spicules, a term not unopen to objection. Many of these simply repeat the forms of the large spicules, but altogether they present a greater diversity and frequently also a greater complexity of form. The minute acerate (*a*) by curvilinear growth becomes tricurvate (*b*) or bow-shaped, or hamate (*c* and *d*), or sinuate (*e*); the sinuate, if spined all over, is a spini-spicule (*e*); and from this we seem to pass to a straight spicule with whorls of spines (*sceptrella*, *g*), or to a spined globule (*globostellate*, Fig. 10, *u*). The C or bow-shaped spicules, by various modifications of their ends, give rise to various forms

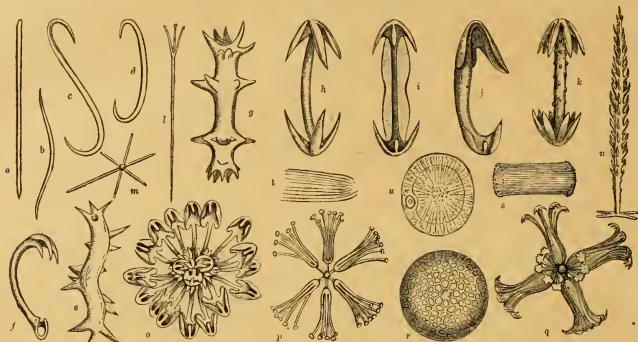


Fig. 11.—VARIOUS SMALLER FORMS OF SPONGE SPICULES. (After Bowerbank, Schmidt, Sollas, and others.)

known as anchorates (*h*, *k*), distinguished as equi-anchorates, if the ends are equal and similar (*h*, *i*), inequi-anchorates, if one is smaller than the other (*j*, *j*). The inequi-anchorates are sometimes clustered together into radiate groups, the small ends meeting at the centre, and the larger diverging at the margin. Rosettes of remarkable beauty (*o*) so produced are common in *Esperia*. The small spicules of the *Hexactinellidae* are, like the large, characteristically sex-radiate; they may be regularly and simply six-rayed (*m*), or the rays may divide into two, three, or more straight or curved secondary rays, the ends of which may be pointed or capitate (*p*, *q*). The anchorates (*k*) of this group are represented by a form which is not obviously sex-radiate; it consists of a central shaft with eight re-curved arms at each end; it sometimes is found in rosettes like the inequi-anchorates of *Esperia*. In this group occurs a nail-like spicule, with a cruciform head, the shaft of which is covered with large spines, all pointing towards the end; these "wheat-sheaf" spicules (*n*) adorn the margins of the oscules of *Meyeria*, the heads being embedded in the skin and the points projecting into the oscule. The broom-shaped spicules shown in the figure (*l*) are characteristic of some Hexactinellids.

Finally, various forms of multi-radiate small spicules are plentiful, the simplest of which consists of a number of fine, hair-like rods (trichites), developed in a fascies-like bundle (trichite sheaf), within a single cell (*s*, *t*). In other forms, the trichites grow radiately outward from a common centre, and, becoming thickened with age, produce a trichite-stellate, or, if they are very numerous, a trichite-globate or globate spicule (*r*, *u*). The globate is characteristic of the most highly developed and complicated of all Sponges, viz., the Geodina. It commences as a minute ball of trichites, the inner ends of which are fused into a little globule at the centre. It is developed within a single cell, with a large nucleus (*u*), and, as it grows, the trichites becoming longer and

stouter, the nucleus remains a little behind in a shallow depression, marked on the adult globate as the "hilum." After the trichites have become strong spines, they grow rounded at the ends, then toothed and roughened for the attachment of ligamentous fibres.

Embryology (Figs. 12, 13).—Notwithstanding the attention which has been paid to the embryology of the Sponges, it is still impossible to bring our knowledge on the subject under a single large

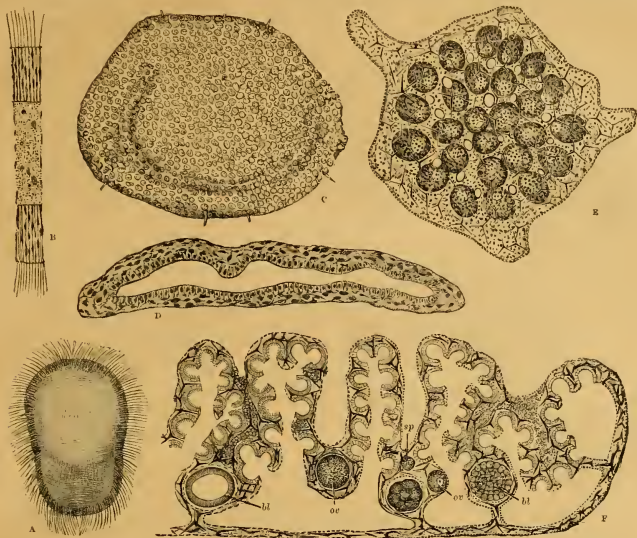


Fig. 12.—DEVELOPMENT OF A SILICIOUS SPONGE (*Plakina monolopha*). [After Schulze.]

A, Free-swimming Planula; B, section of the same, showing epiblast and hypoblast; C, fixed planula with a gastric cavity; D, section of the same a little older; E, young sponge, showing pores and flagellated chambers; F, section across the adult sponge, showing (sp) sperm ball, (ov) ova in different stages of development, and (bl) blastula.

generalisation. Two distinct modes of development have been so far fairly made out, but it yet remains to be seen how far all Sponges conform to these, and how they are related to each other. The ovum in all cases divides first into two, then four, and next eight segments, which, however, are not always equal and similar; by further subdivision, it gives rise either to a solid cluster of cells like a mulberry (morula), or a hollow spherical cluster, the cells forming a single layer about a central cavity (blastula), which normally is completely closed, but, in one instance at least, is known to be open at the poles. The course of development may now become very different, according as a *Planula* or an *Amphi-blastula* is next formed. The planula is a solid embryo (Fig. 12, A) of two layers of cells—an inner, or hypoblast, consisting usually of gelatinous connective tissue, with its stellate corpuscles, and an outer, or epiblast, consisting of small, cylindrical, flagellated cells. The hypoblast originates either by metamorphosis of the internal cells of the morula, or by the budding of fresh cells, which subsequently become metamorphosed, from the inner ends of the cylindrical cells of the blastula. The planula at this stage usually escapes into one of the incurrent canals of the mother Sponge, and is carried out by the outflowing currents into the surrounding water, when it swims

briskly about by the movements of its flagella. It then settles down on some solid body, and flattens out into a disc, which becomes attached by pseudopodia-like extensions from the flagellated cells around its margin. The flagellated cells, losing their flagella, form the pavement-like cells of the ectoderm. Soon after attachment, the hypoblast splits in the middle, and the cleavage cavity so produced becomes lined by flagellated cells differentiated from the hypoblast (Fig. 12, c, d). This layer of cells is the primitive endoderm, the remainder of the hypoblast is the mesoderm. The endoderm buds off flagellated chambers into the mesoderm, and becomes itself converted into plate-

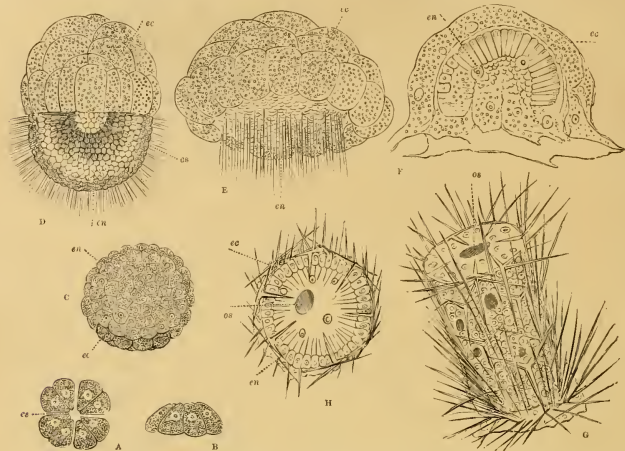


Fig. 13.—DEVELOPMENT OF A CALCAREOUS SPONGE (*Sycandra raphanus*).

A, B, Ovum segmented into eight cells; c, side view of embryo in the blastula stage, eight of the granular cells which give rise to the ectoderm of the adult are present at the lower pole; d, amphiblastula stage; E, a later stage, after the ciliated cells have commenced to become invaginated; F, fixed gastrula stage. The figure shows the anophoroid ectoderm cells (ec) derived from the granular cells of the earlier stage, and the columnar endoderm cells, lining the gastrula cavity, derived from the ciliated cells of the earlier stage; the larva is fixed by the anophoroid cells on the side on which the original mouth opening is situated; G, H, the young sponge shortly after the development of the spicules; G, view from the side; H, view from the free extremity. oe, osculum; ec, ectoderm; eh, endoderm, composed of ciliated cells; c, segmentation cavity. The terminal osculum and lateral pores are represented as oval dark spaces in G, H.

like epithelial cells; pores appear in the walls, and put the flagellated chambers in communication with the exterior (Fig. 12, E), and subsequently an osculum is formed. By a folding of the outer wall, and other changes, a simple excurrent and incurrent canal system is produced (Fig. 12, F).

The amphiblastula (Fig. 13, d) is a hollow sphere, one hemisphere formed of a single layer of small, transparent, cylindrical, flagellated cells (epiblast), the other of large, granular, rounded, and not flagellated cells (hypoblast). It results from a metamorphosis of the blastula (Fig. 13, c), the cells of which, for the greater part, are converted into the small flagellated cells, while a few at the base become granular, and by multiplication produce the larger rounded cells. The next step in the development of the amphiblastula is most interesting and important: the flagellated cells become gradually withdrawn or invaginated into the hemisphere of granular cells; the central cavity of the amphiblastula is thus obliterated, and replaced by another surrounded by the flagellated cells (Fig. 13, E). The embryo now resembles a gastrula of one of the higher animals, consisting, as it does, of a sac with a two-layered wall, and a central cavity communicating with the exterior by a mouth. It soon settles, mouth downwards, on some foreign object (Fig. 13, F), the outer granular cells become the ectoderm, with its usual characters, the inner flagellated cells the endoderm, and a mesodermic layer appears

between the two, probably derived from the epiblast. The embryo now lengthens into a cylindrical form, pores appear in its sides, and an osculum opens at the free end, the primitive mouth having become closed soon after the attachment of the larva (Fig. 13, c, n).

The spicules of the Sponge always develop in the mesoderm, probably in all cases, certainly in some, as the products of single cells. It is a curious fact that they appear in the embryo before it becomes attached, sometimes even before it has left the body of its parent.

Classification.—The position of the Sponges in the organic world was long the subject of controversy, and it was not till after the fundamental discoveries of Robert Grant, in 1825, that their right to a place in the animal kingdom was universally admitted. After the difficulty which had been experienced in making good their claims to an animal nature, it would naturally be expected that they would be assigned but a very lowly place amongst their recognised associates, and accordingly we find them originally relegated to the Protozoa, the lower of the two sub-kingdoms into which the animal world is now divided, the other being known as the Metazoa. The embryological history of the Sponge, and the sub-ordination of its individual cells to the unity of the complex whole which they form, ensured for them, however, the highest place in the sub-kingdom. But they were not long allowed to enjoy an ignoble repose. Already, in 1854, Leuckart advanced them into the higher sub-kingdom as members of the Cœlenterata. At that time, however, naturalists were not prepared to acknowledge the justness of this promotion, and it was not till Haeckel, in a brilliant but too imaginative work, came forward in its support, that it found any general acceptance. Previously, however, in 1866, Professor James Clark had been led, by his discovery of the resemblance of the collared cells of the Sponge to the flagellated infusoria, to regard the Sponges as mere aggregates of these Protozoa, but this view, though earnestly supported by Carter and Saville Kent, is opposed to the general opinion of most naturalists. The searching investigations into the structure and embryology of the Sponges since the publication of Haeckel's views, leave little doubt as to their Metazoic nature. But with regard to the nearness, or otherwise, of their relations to the Cœlenterata, the greatest doubt still exists. The writer originally regarded them as Cœlenterata, which differ from all other members of the class, in the fact that their embryos attach themselves by their oral instead of their aboral extremity, but in spite of certain remarkable resemblances of the larvæ to those of the Cœlenterata the balance of evidence seems in favour of those who, with Balfour, regard the Sponges as forming a separate class, quite independent of the Cœlenterata, and situated at the very bottom of the Metazoic sub-kingdom.

For the subdivision of the Sponges into smaller groups we are chiefly indebted to Oscar Schmidt and Carter, not to forget Haeckel. The accompanying table is founded chiefly on the classifications proposed by them, with modifications, which may possibly be found convenient.

CLASS SPONGIÆ.

Orders.	Sub-orders.	Families.
MYXOSPONGIÆ		{ Halisarcidæ. { Chondrosiadiæ. Ascones. Leucones. Sycones. Renierinæ. Suberitidinæ. Desmacidinæ. Echinomemata. Chalinidæ. Choristidæ. Lithistidæ. Lyssakina. Dictyonina.
CALCISPONGIÆ		
SILICISPONGIÆ	{ Monaxonidæ { Tetractinellidæ { Hexactinellidæ	
CEROSPONGIÆ	{ Ceratinidæ. { Psammomemata.	

MYXOSPONGIÆ.

The *Halisarcidæ**, characterised by the entire absence of any skeletal parts, are represented by the single genus *Halisarca*, comprising a number of small smooth soft Sponges, which grow in

irregular crusts of beautiful colours; sky-blue to violet, russet-red to flesh-colour, pale yellow, carmine, and purple tints being common, though some are colourless.

The *Chondrosiade** are provided with a rough external rind of fibrous connective tissue, and one of the two genera of which the family consists is furnished with stellate silicious spicules; it should therefore be placed in the Silicispongiae, of which it, as well as the remaining genus, which is devoid of hard parts, is probably a degraded descendant.

CALCISPONGIÆ.

These are a small but compact group, which has been closely studied by Haeckel, whose brilliant monograph on the "Kalkschwämme," though marred by a vicious confusion of fact and fancy, has both by its fancies and its facts given a more powerful impetus to the investigation of the whole group of Sponges than any work which has appeared since the time of Robert Grant.

The skeleton here consists of calcareous spicules of various forms, acerate, tri-radiate, and quadri-radiate, the tri-radiate being the most characteristic: they are never collected into fibres nor united together by spongin, but occur separately immersed in the soft tissue of the Sponge, so that after the death and dissolution of the organism they at once fall asunder, and being at the same time very soluble in sea water are so quickly destroyed that it is very doubtful whether they are capable of being preserved in the fossil state. Up to this time no fossil Sponge unquestionably belonging to the Calcispongiae has been described.

They are mostly very small Sponges, often of very regular geometric form; usually white, though sometimes brilliantly coloured.

The Ascones† are simple sacs, with a completely flagellated endoderm; they may be single (Fig. 8), or branched (Plate 71, Fig. F), or in other ways united into a common stock. The Sycones‡ are composite sacs, derived from the Ascones by a budding of Ascon-like sacs radiately from the wall of a parent Ascon (Plate 71, Fig. G). It is a fact of great interest for the theory of development that a continuous or transitional series of species can be shown to exist between a simple Ascon and a Sycon in which the radiate buds have all united together by their lateral surfaces to form a complex tubulated wall (Plate 71, Figs. H, I); and especially that this most complex Sycon passes through the various stages exhibited by these species in the course of its individual development.

One of the common animals of the sea-shore is the little purse-shaped *Sycandra* (*Grantia*) *compressa*, which occurs hanging mouth downwards from the under-surface of rocks, or their attached seaweeds, between tide levels. Sections can easily be made of this to show the tubulated structure of the wall, and by boiling it in caustic potash for a minute or two its beautiful calcareous spicules can be freed from the soft tissues for examination under the microscope. The Leucones§ are characterised by a complicated water canal system, which appears to belong to the same type as that of Euspongia and the majority of the Sponges. The snow-white crusts of *Leucandra nivea* are by no means rare on the under surface of between-tide rocks on the English coasts.

The Calcispongiae have a world-wide distribution, and are found from the sea-level down to a depth of 342 fathoms. Of the 111 species described by Haeckel, nine are cosmopolitan, 68 are found exclusively in the Atlantic, 12 in the Pacific and 22 in the Indian region. No doubt the greater richness of the Atlantic region is due to its having been more thoroughly investigated than the others.

SILICISPONGIÆ.

In this order, characterised by silicious spicules, the Sponges attain their fullest expression and highest development. Its members are the most numerous, the most diverse, and some of them the most complicated of the class. They are spread through all seas, at all depths, and were already in existence in the early Cambrian times. The only family of Sponges (*Spongillina*) which inhabits fresh water belongs to them, and this inhabits the rivers of most existing continents.

The *Monaxonidae* (usually known as the Monactinellidae, which is a misnomer, since it is the one-axedness of their spicules, not their one-rayedness, which characterises them) are distinguished by the presence of uni-axial, and the absence of tetractinellid and hexactinellid spicules. If quadri-radiate spicules do occur in some genera they differ from those of the genuine Tetractinellidae in the

* Greek, *chondros*, gristle.

† Greek, *ascon*, a wine-skin or leathern bottle.

‡ Greek, *sycon*, a fig.

§ Greek, *leucos*, white.

fact that the three additional rays are given off from the hinder (proximal) end of the shaft and not from the anterior (distal).

By Oscar Schmidt this sub-order is divided into the five following families:—

Families, O.S.	Orders, Carter.
Renierinae	
Desmacidinae	Holorhaphidota.
Suberitidinae	
Chalinopsidinae	
Chalininae	Echinonemata (pars)
	Rhaphidonemata.

Carter's classification of these Sponges is shown in the table.

In the Renierinae* the chief spicules are usually bi-radiate (acerate), and are generally collected to form fibre, in which they are arranged like the elongated cells in the woody fibre of plants. Spongin may develop about this fibre, cementing the spicules together, and then the Renierina becomes a Chalinine Sponge, but so easy is the transition between these families that Carter makes mention of a Sponge which is Renierine or Chalinine, according to the locality in which it is found. The Renierinae are among the commonest of Sponges, and are well represented on the British coasts; the hardy *Amorphina panicea*, or "Crumb of Bread" Sponge (Fig. 3), found at most watering-places, is a good example. It grows in thick crusts, of a plant-green colour, rising into little conical volcano-like elevations, which open by an oscule at the summit; pores occur in the skin over the interspaces of a very regular spiculous network which lies beneath. Its spicules are simple acerate, sharply pointed at each end, and crowded loosely together into indefinite fibre, which forms an altogether irregular network in the body of the Sponge. From this loose texture, and the fact that owing to the absence of spongin, the Sponge readily crumbles between the fingers when dry, it derives its name of "Crumb of Bread" Sponge.

Another common example is the *Spongilla fluviatilis* of our rivers. It occurs in irregular masses of much the same colour as *A. panicea*, with which it closely agrees in general structure; it differs, however, in common with the sub-family Spongillina, to which it belongs, both from that and all other Sponges, in the fact that it reproduces itself not only by ova, but by curious little bodies (Fig. 14) known as winter-eggs, or statoblasts, which somewhat resemble the statoblasts of the Polyzoa. Their history has been the subject of a classic memoir by Carter, who finds that they originate near the base of the Sponge, by certain cells congregating together and becoming surrounded, except at one point, by a spherical shell, a pin's-head in size, of complicated structure, its external layer consisting of spicules of singular form, like a pair of wheels on an axle in miniature. The axle lies radiately in the wall. The spot where no shell is formed remains as an aperture, through which in spring, the anæbiform contents creep out from their winter quarters, and soon develop into the young Sponge.

The various members of the sub-family Spongillina do not differ except in trifling details from *Spongilla*; though they have not yet been described from Australia, they are otherwise of world-wide distribution, and from this we may infer that they are a group of great antiquity. Owing to the rarity of fresh-water fossils, and the exceptional preservation of Sponge remains, it is not to be expected that we should find direct evidence of this, and it is, therefore, all the more satisfactory that traces of *Spongilla* have been found so far back as the Purbeck strata, where its chief spicules have lately been detected in fresh-water chert.

Spongilla is so similar in many respects to *Amorphina*, which sometimes lives in brackish water, that it is very possibly derived from it. It is a singular fact that of the many hundreds of widely different kinds of Sponge, none but a small rigidly-defined group should be found inhabiting inland waters. This is probably due not to the inability of Sponges to adapt themselves to fresh water, but rather to the fact that they are propagated by ciliated larvæ, which drift about at the mercy of

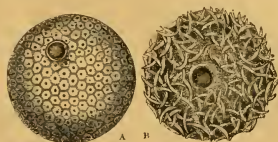


Fig. 14.—STATOBLASTS OF SPONGILLA.

A, Statoblast of *S. fluviatilis*, in its natural state, $\times 50$; B, of *S. locustrea*, after treatment with nitric acid, $\times 96$.

* After the naturalist Renier.

every current, and cannot, therefore, ascend a river where the current is always seaward. This explanation will probably account for the absence of many other marine forms of life which one might expect to find amongst the fauna of our rivers.

The statoblast is no doubt an adaptation to preserve the Sponge from the extreme climatal changes to which fresh water is exposed; thus in Bombay it develops at the time of summer droughts, in temperate climates on the approach of winter. It is worth noticing that the statoblast of the Polyzoa also occurs only in the fluviatile forms.

Suberitidinae.*—In these Sponges the spicules are characteristically pin-shaped, densely aggregated together, either in fibres, or matted felt-like. The surface often bristles with the projecting points of radiating spicules (Plate 71, Figs. K, L), but is never provided with a regular spiculous network like that which usually occurs in the Renierinae.

The large Sponge appropriately named Neptune's Cup (*Poterion neptuni*,† Fig. 9, c), found growing on the coral reefs of the Indian Ocean, and fossil in the English Chalk, is a Suberite. A near relation, possessing the same pin-like form of spicule, is the little burrowing Sponge *Cliona*, which eats its way into shells, particularly oyster-shells. Shells so infested may often be seen at the fishmonger's. They may be at once distinguished by the numerous round holes which cover the surface. The holes are of two sizes, the larger for the emission of oscular tubes, the smaller, which are much more numerous, for poriferous tubes. On splitting the shell open both are found to communicate with irregularly swollen canals, which are occupied by the yellowish-coloured body of the Sponge. If the oyster, fresh from the sea, be placed in a vessel of cool clear sea-water, a beautiful sight will soon present itself. From the various apertures delicate mobile tubes protrude. Those from the larger end in a single oscular opening; those from the smaller expand at the end into a conical form, resembling, with the swollen base perforated by numerous little pores, the "rose" of a watering-pot, with the addition that here the margin of the "rose" is fringed with a corona of delicate diverging spicules. The tubes are very sensitive not only to touch, but to the incidence of light, instantly contracting and withdrawing themselves when exposed to powerful sunlight. Currents of water flow into the poriferous tubes, which swing to and fro, seeking the water most to their taste, and from the equally mobile oscular tubes currents briskly escape. In autumn, this sponge-mass will be found crowded with little oval yellowish bodies, about $\frac{1}{16}$ th of an inch long, which are the ciliated embryos or larvæ of the Sponge. Spicules are already developed in them. The burrows of *Cliona* occur in fossil shells of the Silurian strata.

Desmacidinae.—This is the culminating group of the Monaxonidæ, distinguished by the rich variety of its spicule forms. Besides the chief spicules, which are usually bi-radiate (acerate or acuate), there are always present one or more forms of small spicules, C- and S-shaped hamates; tri-curved; equi- and inequi-anchorates, singly dispersed or clustered into rosettes; and trichite-sheaves. It is from this group that the Tetractinellidæ have probably been derived.

Echinonemata.‡—The skeleton is characterised by Carter as composed of chief spicules lying parallel to form a fibre, which is spined by other (echinating) spicules projecting from it. Schmidt considers the absence of hamates and anchors essential to the definition of the Chalinopsidinae, a group otherwise equivalent to the Echinonemata. Spongin is usually present, cementing the spicules together; it may increase in quantity, replacing the spicules, which may diminish to a single row, or disappear from the interior, the echinating forms of course persisting. Should they also vanish, the Sponge would become a Cerospongia.

Chalinidæ.—The common *Chalina oculata* of the British coasts is a good example of this group. The skeleton consists of spongin fibre, cored by silicious spicules, which are usually monaxial; echinating spicules are absent. The relative development of the spicular axis and the spongin wall is very variable, some, like *Pachychalina*, approaching the Renierinae by the preponderance of spicules; others, like *Chalina*, approaching the true horny Sponges (Cerospongia) by the excessive development of spongin. This family, indeed, links together the Silicispongiæ and the Cerospongiæ, and since its spicules must apparently be formed before the spongin which envelops them, it would appear rather that the Cerospongiæ were derived from the Silicispongiæ by loss of spicules, rather than the latter from the former by their acquisition.

* Latin, *suber*, cork.

† Greek, *poter*, a drinking cup.

‡ Greek, *echinos*, a hedgehog; *nema*, a thread.

The Monaxonidæ are cosmopolitan, chiefly shallow-water forms. They range from the strand-line down to 862 fathoms; on the evidence of Cliona borings in Silurian fossils they are concluded to have been in existence in early Palæozoic times; fossil remains of their skeletons are rare, *Pharetspongia strahani* (Sollas) of the Cambridge Greensand, a large Renierine Sponge with a fibrous skeleton, being the best preserved and most certainly demonstrated example yet known.

Tetractinellidæ.—This sub-order embraces two very different groups; the *Choristidæ*, in which the spicules are separate from each other, and the *Lithistidæ*, in which they are united by the interlocking of their branched ends into a dense stony network.

In the *Choristidæ*† are united a number of very different types of Sponges, of which the *Geodina* are best known. In these the body, usually more or less spherical, is differentiated into an external rind and an inner mark, or parenchyma, like an orange; the rind (Fig. 15) consists of a layer of fibrous connective tissue, covered externally by the ectoderm and a layer of minute flesh-spicules; its outer two-thirds is crammed full of spicules, usually trichite-globules (mistaken by Bowerbank for ova), which give to it great firmness and consistency. The incurrent canals in their passage through the rind present a very definite, usually hour-glass form, the constricted part being defended by a sphinctral muscle, produced by a modification in the character of the surrounding fibrous layer. The chief spicules are large acerates, which lie in bundles or fibres radiating towards the surface, near which some of them divide into three rays, forming forks and anchors.

The *Lithistidæ*‡—Notwithstanding the firmness of their coral-like skeleton these are no more characterised by constancy of form than the other groups of Sponges; they usually affect cup-like, lamellar, top-shaped, or cylindrical forms, are occasionally branched bush-like; generally attached, sometimes by a longer or shorter stalk, which branches out root-like below. Their skeleton consists of the united body-spicules (Fig. 10, *k*); of surface spicules, anchor- or fork-shaped, or disciform; and minute so-called flesh-spicules. Differences in the character of the body-spicule have afforded Zittel a means of dividing this group into four families, in one of which, the *Megamorina*, the quadri-radiate form of the body-spicule is nearly lost, and the central canal or axial-thread has a simple uniaxial form (Fig. 10, *m*).

The *Lithistidæ* occur in the Atlantic, Pacific, and Indian oceans; they are essentially deep-sea dwellers, ranging from 74 to 805 fathoms. By reason of the comparatively large size of their body-spicules, and the union of these into a stout resistant framework, they stand a much better chance of fossilisation than the Monaxonidæ; they are accordingly by no means rare in a fossil state, and have been found in most marine formations from the Upper Cambrian to the Tertiary. The well-known *Siphonia* of the Blackdown Greensand is a familiar instance (Fig. 9, *d*).

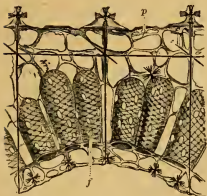


FIG. 16.—SECTION THROUGH THE WALL OF EUPLECTELLA ($\times 75$). (After Schultze.)
p, pores; f, flagellated chambers.

A slight deposit of silica may unite together the spicules of some *Lyssakina*, e.g., *Euplectella*, but never to the extent of completely enveloping them.

The *Lyssakina*§ include such forms as *Holténia*, a somewhat cylindrical Sponge, with a large

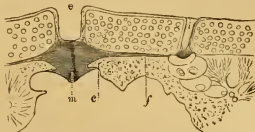


FIG. 15.—SECTION THROUGH THE RIND OF A GEODINE SPONGE. (After Sollas.)

e, gelatinous connective tissue; c, excurrent canal, closed by the muscle (m); f, fibrous tissue; i, incurrent canal.

* Greek, *tetra*, contr. of *tettara*, four; *actis*, a ray.

‡ Greek, *lithos*, stone.

† Greek, *choris*, separately.

§ Greek, *lysis*, loosening.

central oscular tube fringed by whisker-like spicules, and a thick beard-like growth of anchoring spicules, which serve to support it in the soft slimy ooze of the deep sea in which it lives; *Hyalonema** (Fig. 9, B), the Japanese glass-rope Sponge, a close ally of *Holtentia*, but at once distinguishable from it by the spiral wisp or rope into which its anchoring spicules are twisted together; the upper end of the rope is overgrown with encrusting *Palythoa*, the lower end frays out by the divergence of the spicules; deprived of the Sponge the rope may often be seen in private houses stuck topsy-turvy under a glass-shade; an instance of the perverted ingenuity of the Japanese divers by whom it is obtained and "prepared."

Euplectella† (Fig. 9, A), with a framework so exquisitely beautiful in its fairy-like tracery as to have called forth the remark from a distinguished naturalist "this passes the love of woman," has now also become an ornament to glass-shades; it is a Lyssakine, with spicules so arranged crossing one another as to weave together a thin-walled vase of delicate lattice-work with square meshes. In the

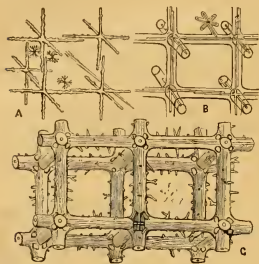


Fig. 17.—A, SEPARATE SPICULES OF A LYSSAKINE SPONGE; B, SPICULAR NETWORK OF A DICTYONINA; C, DICTYONINE NETWORK WITH OCTAHEDRAL KNOTS. (After Marshall and Zittel.)

Euplectella terminates below in a tuft of anchoring spicules; but when it is found in shallower water on a hard bottom it becomes attached, and its anchoring spicules abort.

In the Dictyonina‡ the chief spicules are so disposed that by the overlapping of their rays they form a framework, which afterwards being overrun by silica becomes a continuous net; the knots or nodes of this net correspond generally with the centre of the spicules, its connecting fibres with two overlapping rays (Fig. 17, B). The spicules are not always so regularly arranged as in the figure; and in many genera they depart widely from a three-axed form, the rays diverging at all angles, so that one fibre may contain more than two and as many as all six rays. Loose sex-radiate spicules are always associated with the network, and delicate minute or flesh spicules are general throughout the Sponge. The "flower-basket" sponge *Dactylocladia* (Fig. 9, E), the earliest discovered instance of a Hexactinellid, is a good example of this group, and *Farrea* is another, distinguished by the regularity of its square meshes. In some Dictyonina the investing silica fails to completely fill the angles at the centre of the spicules, but stretches across in fine threads from one ray to another, sketching out the edges of a regular octahedron, with the spicular rays for its axes. This structure was accurately described long before it was understood, by Touthin Smith, who showed that it characterised the network of the Ventriclelites. It is only quite recently that an existing Sponge has been described (*Myliusia*) in which the same structure prevails (Fig. 17, C).

The Hexactinellide inhabit all seas, and are found in deep water, ranging from 98 to 1,591 fathoms, and probably more. They make their appearance in time very early, remains of a Lyssakina (*Protospongia*) being found in the Lower Cambrian rocks at St. David's, South Wales; both Dictyonina and Lyssakina occur in the Silurian of North America; in the Carboniferous

* Greek, *hyalos*, glass.

† Greek, *eu*, well; *plectos*, woven.

‡ Greek, *diction*, a net.

of Scotland, a genus, *Acanthospongia*, closely allied to *Hyalonema*, has been described by Professor Young, of Glasgow, and later by Mr. Carter. In the Jurassic strata Hexactinellids are well represented, and in the Chalk they abound, the graceful and varied *Ventriculites* being well known to collectors in the Downs of Sussex.

CEROSPONGIA.

This order consists of Sponges with a spongin skeleton, but without proper spicules. The axis of the spongin fibre may be occupied by soft organic matter only (*Ceratina*), or it may involve various foreign bodies (*Psammonemata*) [Greek, *psammos*, sand]. The Bath Sponge, already fully described, is a member of the *Psammonemata*. *Luffaria*, of which an illustration is given in Plate 71, belongs to the *Ceratina*. No examples of these widely-distributed sponges are yet known in the fossil state.

The literature of the Sponges is copious, but much of it very inconveniently scattered in separate memoirs through journals and magazines. For general information, and descriptions of species, may be quoted Oscar Schmidt's volumes on the Sponges of the Coast of Algiers, of the Atlantic Ocean, and of the Gulf of Mexico; Haeckel, *Die Kalkschwämme*; numerous papers by Carter in the "Annals and Magazine of Natural History," where also papers by Sollas appear; for masterly accounts of structure and embryology see F. E. Schulze in several numbers of the "Zeitschrift für Wissenschaftliche Zoologie," where also are papers by Metschnikoff and Oscar Schmidt. A history of the Sponges will be found in George Johnston's "British Sponges," and good descriptions of British species in Bowerbank's "Monograph on the British Sponges," 3 vols. Jules Barrois has published "Researches on the Embryology." For fossil Sponges see the fine works of Zittel, and papers by Sollas in the *Quarterly Journal of the Geological Society*.

W. J. SOLLAS.

THE RHIZOPODA.

The Rhizopods—Appearance—Protoplasm or Sarcode—Its Character and Functions—The “Contractile Vesicle”—*Amœba* and *Monera*—True “Cells”—Assimilation of Food—Contents of the Endosarc—The “Vacuoles”—Food of the *Amœba*—Naked Lobose Rhizopods—Shelled Lobose Rhizopods—Sun-animalcules—*Actinophrys* *sed*—The Radiolaria—The Polyistina—The Reticularia—The Foraminifera—Imperforate or Porcellanous Foraminifera—Perforate or Vitreous “Forams”—The Flagellata—Gregarinæ—The Link Connecting the Rhizopods and Vertebrates—Bibliography—Classification.

I. Among the minute animals which escape our naked sight, but may be seen by the aid of a magnifying glass in some instances, but often only under the far stronger lenses of the microscope, are those which are known as Rhizopoda,* or Myxopoda.†

They have, in a great degree, the same simple constitution as several other kinds of animalcules which are grouped by naturalists as Protozoa,‡ such as Infusoria § (also Sponges), their essential living material being merely a structureless and jelly-like or mucons substance; and thus they stand as the *first* in the scale of animal organisation, as it rises from the most simple to the more highly organised animals with their manifold tissues and complicated structures.

II. The delicate albuminous material of the Rhizopods and their allies is a “semi-fluid, nitrogenous, formative substance,” termed “Protoplasm,”|| as being the simplest or *first* life-matter known to us. It is also called “Sarcode,”¶ as supplying the place of flesh, rather than being flesh-like itself. It is probably composed of carbon, hydrogen, oxygen, and nitrogen, like some other organic compounds; and it is the physical basis of life in both animals and vegetables.

This slimy, white-of-egg-like sarcode of the Rhizopods, though granular, with exceedingly fine particles, and to some extent differentiated by local formation of special groups of granules, known by some as “Endoplasts,”** shows no definite parts or divisions of a body such as characterise higher animals; nor has it permanent limbs, nor body-cavity, nor alimentary canal, nor nerves, nor blood. Nevertheless, it serves for and fulfils all the necessary actions and processes of life.

Its outer portion is generally distinguishable from the interior, and is sometimes toughened into a kind of membrane, or hardened with mineral matter into a shelly coat, or a stiff skeleton of network.

More especially this corpuscle of sarcode has in itself a particular kind of motive plasticity, whereby it can advance with a slowly-flowing movement of all or a part of its substance. In the latter case, the elongated portions, whether thick or thin, are termed “Pseudopodia.”††

The constituent atoms or granules, moreover, in their glairy slime, are mutually, if not equally, engaged in the functions of movement and of assimilation of nutriment, and in the multiplication or reproduction of individuals. In the active animal they seem to flow in a kind of circulation through the little mass, and along the protruded lobes or threads; and in many cases form special aggregations of granules, or endoplasts. The smaller of these are termed “Sarcoblasts,”‡‡ and may be regarded as ovules, or little eggs, formed within the parent, and when free, by escape or by emission, becoming new little beings like the parent. A larger endoplast constitutes the “Nucleus,” in the middle of the animalcule. This internal corpuscle seems to be essential to the economy of most of the Protozoa, forming, as it were, a starting-point of one kind of germination; and it is the first representative of a permanent vital organ.

Another prototype or forerunner of more highly constituted organs is a minute bladder-like collection of clear fluid, which in some part or other of the body, but generally towards the hinder end, is seen to increase slowly to fulness; then, suddenly contracting, to collapse and become empty, at almost regular intervals of time. This “Contractile Vesicle” seems to be analogous to, if not really, an organ of secretion and distribution.

* Greek, *rhiza*, a root; *pous*, a foot.

† Greek, *myxa*, mucus; *pous*, a foot.

‡ Greek, *prôtos*, first; *zôon*, an animal.

§ So called from having been first found in infusions of hay and other vegetable matters. But many of the little creatures first grouped under the name have been separated off, and the *Infusoria* are special protozoan animalcules.

|| Greek, *prôtos*, first; *plasma*, a formation, from *plasso*, I shape or mould.

¶ Greek, *sarz*, flesh; *cidos*, form or appearance.

** Greek, *endon*, within; *plastos*, formed or moulded.

†† Greek, *pseudos*, false; *pous* (*podos*), a foot.

‡‡ Greek, *sarz*, flesh; *blastos*, a germ.

III. The above-mentioned characters may be readily observed in one of the most common forms of Rhizopods, namely, the *Amœba*,* or proteus-animalcule, so called on account of the ever-changing shapes which a well-conditioned active individual puts on while moving under the microscope, and pushing out and drawing in the various projections on its surface, sometimes like fingers or threads, called pseudopods.

There are, however, certain living atoms of protoplasm so simple in condition, being quite structureless, except in having constituent granules, that some naturalists have separated them from the *Amœba* and the other Rhizopoda in classification, and called them *Monera*;† not so much in view of their singleness, as on account of their unity of composition. They may, however, be intermediate forms, or passages from one stage to another in the growth and development of certain animalcules. Some of them may even be the germ-products of low plant-structures.

Some appear to be so destitute of any structural features that their slime-body shows no distinction between the outer and inner parts, and has no nucleus; and their free, homogeneous, jelly-like substance, in moving, stretches itself out in one direction or another in lobular, finger-like, or filamentous prolongations, and contracts again, either over such organic atoms as seem to be its food, or towards a point where such a protruded part has adhered and fixed itself.

Some such amœboid creatures are shown in Fig. 1; and their elementary simplicity has originated for one kind the name of *Protamœba*,‡ and for another, *Protozenes*.§ The latter is a relatively large and outspread mass (three or four millimètres in diameter) of such protoplasm as is known as a "plasmodium."|| This is similar to the protoplasm of the much smaller *Protamœba* (scarcely $\frac{1}{10}$ th of a millimètre in width), but is made up of a combination of many such individuals.

Reproduction of the species is carried on either by the separation of individuals from the parent mass, by their splitting off, or by the parent dividing into two.

Other *Monera* begin life like the *Protamœba*, but after a while they cease to be active, becoming quite still, and enter on what is known as the "resting-stage" in Infusoria, the *Amœba*, and other animalcules. In this quiescent state they are round, and become enclosed in a tough coat, and are said to be "encysted,"¶ until before long the enclosed morsel of protoplasm resolves itself into numerous definite minute bodies, each capable of living by itself when set free, and hence termed "Zoöspores."** Sometimes these tiny corpuscles, combining together, form a new gelatinous mass (plasmodium), like that of the parent, as in *Protomyxa*†† and some other relatively large Moneres, not nucleated in every stage of their growth, creeping by means of their soft mobile body at first, and afterwards by the contractile filaments of their sarcode, which branch out and form delicate reticulations, with irregular meshes, as in some Rhizopoda. As these animalcules, closely as they may be related to the Rhizopods, differ from them somewhat in their mode of growth, and in their changes from one stage to another, they have been grouped in some classifications under other distinctive names, such as *Myxomyceta*,‡‡ *Myxogastrea*,§§ and *Mycetozoa*.||| It is difficult for botanists to regard them as belonging to the animal kingdom.

IV. The above-mentioned lowly creatures of the *Amœba* and *Protamœba* types show a close analogy to the elementary "cell," which, in some condition or other, is known to be at the foundation or commencement of all kinds of animal and vegetable tissues. A "cell" consists of a minute sac, or bladder-like envelope (the "cell-wall"), and an enclosed morsel of fluid or semi-fluid gelatinous

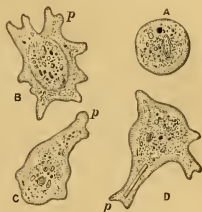


Fig. 1.—AMÆBA PROTEUS.

A, in the contracted or "encysted" state; B, C, D, in motion; p, p, pseudopods pushed out in action. Highly magnified.

* Greek, *amoibē* (amœibo) exchange.

† Greek, *prōtos*, first; *amœba*.

‡ Greek, *plasma*, a formation; *eidos*, appearance.

** Greek, *zōē*, life; *sporos*, a seed.

†† Greek, *myxa*, mucus; *myces* (gen. *mycetēs*), a fungus.

§§ Greek, *myxa*; *gastre*, the bottom of a vase, or the hold of a ship.

+ Greek, *monos*, alone.

§ Greek, *prōtos*, first; *gēinomai*, I am born.

* Greek, *en*, in; *kistis*, a bladder.

†† Greek, *prōtos*, first; *myxa*, mucus.

||| Greek, *myces*, a fungus; *zōon*, an animal.

protoplasm (with its innumerable floating molecules, granules, or globules), possibly a network of filaments, and a more or less solid "nucleus"; and this last has often within it an almost immeasurably small but distinct spot called the "nucleolus." Such "cells," being endowed with vital force, can absorb and use up water and organic fluids; they have the power of growth, of secreting new materials, of producing similar "cells," capable of the same functions as those of the parent "cell" (and even more advanced functions); and in many cases they can move freely. The "nucleus," secreted or formed by the protoplasm, seems to regulate these vital phenomena, especially germination or reproduction, for it multiplies itself by "fission," by breaking up into germinative particles, and by the formation of "nucleoli," which, in their turn, become "nuclei."

Even without a "cell-wall," the *Amœba* is a true animal "cell"; but the *Protamœba*, having

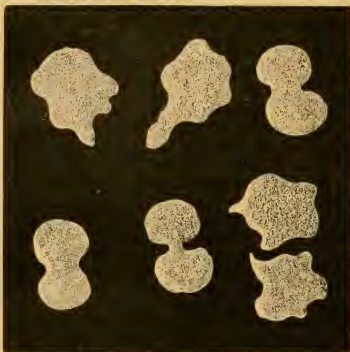


Fig. 2.—*PROTAMOEBA PRIMITIVA*.

Showing some of the stages during the process of fission. Very highly magnified. (After Hæckel.)

neither "cell-wall" nor "nucleus," represents only the simple protoplasm of a "cell." Such living corpuscles have been termed "Protoplasts" by some, and "Cytodes"* by others. Such are the free-moving *Monera* (*Protamœba*), the non-nucleated plasmodia of the *Myxomyceta*, and the amoeboid germs of *Gregarina*, proceeding from the "pseudonavicula." That all these simple organisms, however, are true animals has not yet been satisfactorily determined.

"The *Amœba*, however," says Hæckel, "presents the most simple form of a single-celled ('unicellular') organism in a complete state of development, and in some sort the ideal of an animal 'cell.' Widely distributed in fresh waters, on muds and wet earth, and occurring in brackish and salt water also, these animalcules are of special interest on account of their eminently simple structure as a 'cell,' and because of the bearings of their development and functions on the history and meaning of other 'cells.'"

V. Thus the *Amœbe* may be said to be

soft, naked, nucleated "cells," of indeterminable shape. They move here and there in water, sometimes floating, but usually creeping on plants and other objects by protruding from any part of the surface of their body, but more especially from one end, and that the broadest and most translucent, variable finger-like lobes of their own body-substance, and then either retracting these processes, called "pseudopods," or drawing the body to the point at which they fix themselves. Of course the body varies indefinitely throughout these movements (see Figs. 1, 2, 3), being at one time nearly circular, at another angular, and then jutting out at corners or at the sides with capes and peninsulas of no fixed shape, and ever slowly shifting, as if a floating island, restless and bewitched, gained and lost its coasts again and again at the caprice of some changeful sprite, aiming at fancied resemblances to hands, antlers, or branches, and back again to more solid but clumsy shapes of leaves and buds, and even slugs or imperfect stars.

"The changes of form produced by the extension and branching of certain of the pseudopods, with the recession, melting away, and total disappearance of others, is endless. Sometimes the animal creeps onward in a flowing manner with comparatively simple cylindrical form, occasionally emitting a single pseudopod on one side or the other. More commonly in movement it assumes a dendroid or palmate appearance, or sometimes, diverging from the directly onward course, it becomes more radiate. Not infrequently it assumes more or less grotesque shapes, in which almost every conceivable likeness may be imagined."—Leidy, "Freshwater Rhizop. N. America," 1879, p. 36.

* Greek, *cytos* (plural *cyta*), a hollow; *eidos*, appearance.

Organic morsels over which these *Amæbæ* softly glide are taken into the plastic body, sometimes at any spot, but generally at a particular region, where the clear sarcode is thinnest; and water is also absorbed or enclosed. Thus the acts of eating and drinking, without mouth and stomach, are accomplished; and assimilation (rather than digestion) of the good and available portions of the prey duly takes place.

After continued growth, the body sometimes divides into two living individuals; but it often becomes almost wholly a mass of zoospores, so that the once unicellular creature is converted into an uncountable multitude of living "cells" or simple animals.

Thus also the "cells" in our own bodies play their part; multiplying new "cells," and replacing those which have been used up. More especially the white globules of the blood of animals are ameboid. As they circulate along the vessels, they execute movements like those of *Amæbæ*, ever modifying their shape; and they can be made to enclose foreign substances (such as carmine), just as the *Amæbæ* takes in its food. Further, a simple *Amæbæ* has a striking resemblance to the "primary cell" or "ovum" of all animals, whether vertebrate or invertebrate. It may be regarded as equivalent to this unicellular phase of higher organisms. As a vital mass of the simplest and most elementary formation we can conceive, it is adapted for a very low stage of existence, having only the properties of locomotion, assimilation, and reproduction. Having such an extremely rudimentary formation, many of the Protozoa have been regarded as members of the Vegetable Kingdom, and as mere germs of some plants. Hæckel places many of them, as *Protista*, in an intermediate position. The *Amæbæ*, however, and its numerous allies, prey on organic substances, and even on living organisms, after the manner of animals. But in this great group they take their place, in classification, according to the relative absence of those special organs which characterise the higher members of the kingdom.

VI.—The sarcode of the *Amæbæ* is often yellowish from its contained granules; but it is nearly transparent at one, usually the broader, end of the body in active individuals; whilst the granules, germinal and other globules, and particles of food, more or less digested, with green, yellow, brown and other tints, crowd and darken its hinder part. The edge of this, under the microscope, looks like a pellucid coat (in section) by transmitted light; and being free from coarse particles, invests, as it were, the thicker interior with a thin layer of sarcode. The more coarsely granular and inner material is called the "Endosarc;"* the other is the "Ectosarc,"† or "Diaphane."‡ They are really interchangeable; the outer surface, which is toughish, without being coated with any membrane, may be turned in and becomes as soft as the rest of the sarcode, especially when the prey is engulfed and takes in some of the intumed ectosarc with it.

The contents of the endosarc appear to be:—1. Granules of various kinds—some exceedingly minute and protoplasmic, others relatively large, some of which are apparently like water, some like oil, some like starch; 2. Newly ingested food—some soft (Desmids, &c.), some hard (Diatoms)—and food-balls of partly digested food, which soon become broken up as loose particles in the endosarc; 3. Water-vacuoles, either independent or investing morsels of food, and probably arising from water engulfed either by itself or with the food; 4. Quartz sand sometimes, and "in some fine, large, vigorous specimens of *A. proteus*, collected from a pond in the vicinity of a saw-mill," Dr. Leidy found that "the endosarc contained multitudes of particles of sawdust;" 5. Minute crystals, regular in form (octahedrons and others); 6. Sarcoblasts; 7. The nucleus; and, 8, the pulsating or contractile vesicle. There may be more than one of each of these.

* Greek, *endon*, within; *sarz*, flesh. † Greek, *ektos*, outside; *sarz*. ‡ Greek, *diaphanes*, transparent.



Fig. 3.—*AMEBÆA PROTEUS*, WITH PSEUDOPODIA ADVANCED TO THE RIGHT, AND A LARGE NAVICULA ENVELOPED IN THE DISTENDED HINDER PART. THE PAPILLARY OR MULLBERRY-LIKE EXTREMITY IS SEEN TO THE LEFT OF THIS.

n, Nucleus; cv, contractile vesicle; the dark spots are food balls and food vacuoles. Magnified 500 diameters. After Leidy.

The wider, often fingered, and always forward-moving, clear part of the body has been observed to be not so viscid and sticky as the narrower, coarse-grained, food-carrying hinder portion; and the food has been seen to be taken in by the creeping mass, as it flows on like moving slime, more frequently just about the place where the clear passes into the granular part, than at other parts of the body. Yet even one or more of the pseudopods can take prey by enwrapping it and passing it on to the interior.

All the granules, whether of partly digested food, or germinative spherules, or protoplasmic atoms, are often seen to stream forward along the middle of the animalcule, encroaching sometimes on its clear moiety, and then to return down each side, to be swept forward again, with varying energy, in a kind of circulation or "cyclosis."* But this is associated with the movement of the animal, and is not analogous to a systematic blood-circulation.

The process of digestion or assimilation is as yet a mystery of organic chemistry. The refuse of the food is gradually accumulated in small lots towards the hinder end, and is let out now and then through the clear sarcodæ of the surface. Germinal granules or zoospores sometimes escape at these opportunities.

When a lobe or pseudopod is pushed out, the miscellaneous particles of the endosarc appear to rush toward the new projection; but for the most part only the sarcodic granules follow it up and continue the "cyclosis" in its substance.

The protrusion of a pseudopod is often preceded by an energetic contraction of the pulsating vesicle; and it has been remarked that, though there is no apparent opening in the common *Amœba* for the contents of this vesicle to escape outwardly, it is always at or near the surface of the hinder end when emptying itself. In some cases it may force its fluid far among the atoms of the protoplasm, whether as nutritive or excretory matter. It acts best when the animalcule is in good condition; and then it is that the movements of pseudopods or other superficial parts are seen to follow its contraction. In a large *Amœba* with a villose patch at its end, Dr. Wallich thinks it probable that each ruptured vesicle leaves a ragged edge, which hardens too soon for it to be wholly absorbed into the general sarcodæ, and thus leaves outstanding morsels (villi) of permanently indurated ectosarc.

There are also visible in the *Amœba* one or more of the clear spots already referred to, which do not fill and collapse at regular intervals. These are known as "vacuoles."† Some are "water-spaces," and seem to be relatively persistent; others are formed temporarily round large particles of food. The following lucid description of such a "food-vacuole," from the pen of Prof. P. Martin Duncan, is especially apt:

"A large *Amœba* with a very delicate endosarc had been feeding on broken-down Confervæ, spores, and green cells, when a tolerably large Diatom, a *Pinnularia*, came in contact with its small end. The scanty diaphane then immediately increased in quantity and flowed over the intruder, which sank, as it were, gradually into the endosarc, and remained in one part of it. After a few minutes had elapsed, a clear space formed in the *Amœba* around the prey, which immediately began to move in it backwards and forwards after its usual fashion. The space was evidently filled with water, and therein moved the captured Diatom, apparently in no great discomfort. After long watching, it became apparent that the size of the space, or *vacuole*, as it is termed, increased, and that the Diatom became stationary and ragged-looking, and, in the course of more than a day, it split and separated into two halves. After this the vacuole disappeared, and the relics of the meal were jumbled up in the group of granules and other digested bits which streamed about in the endosarc."‡

Dr. Leidy observes that the food of the *Amœba* commonly consists of "various Diatoms, Desmids, green unicellular Alge, and spores of the filamentous Alge. Considerable fragments of the latter, such as *Oscillaria*, *Zygnema*, &c., are also often seen among the food contents. Occasionally animal forms may be detected in the food materials in the endosarc, among the most common of which are the Rotifers; and in several instances I have observed with them an unfortunate Arcella, a *Diffugia* or a *Trinema*." Dr. Leidy also describes and

* Greek, *cyclos*, a circle.

† Latin, *vacuus*, empty; hence a "diminutive," *vacuolum*.

‡ "Popular Science Review," new series, vol. i. p. 232.

figures the capture, swallowing, and digestion of an *Amœba verrucosa* by a cannibal (*A. proteus*). Elsewhere Dr. Leidy gives an account of another capture:—"In one instance I saw an individual (*A. proteus*) containing, within a large vacuole, an active Infusorian (a *Urocentrum*), and having a second victim of the same kind included in the fork of a pair of pseudopods, the ends of which were brought into contact, so as to imprison the animalcule within a circle. The latter moved restlessly about within its prison, but after a time became motionless, and shortly after the ends of the pseudopods which enclosed it fused together. . . . Fibres of ectosarc extended from the body of the *Amœba* towards the fused ends of the pseudopods, and finally the *Urocentrum* was enclosed in a vacuole like that in the interior of the body of the *Amœba*. Having carefully watched the latter for some time, the two vacuoles containing the captured *Urocentrums* were seen gradually to diminish in size, the contents were reduced to the usual size of the ordinary food-balls of the endosarc, and all trace of the previous character of the victims was completely lost." Dr. Leidy adds that "the different food-materials undergo chemical changes as a result of digestion in the endosarc, and colours become changed in a striking manner. The bright green chlorophyll of Algae becomes brown or yellow, and shrivelled within the colourless cells; and the endochrome of Diatoms becomes browner in tint, and shrivelled into two narrow strings within each shell."

Dr. Wallich has watched the process of a *Furcularia* eating pieces out of an *Amœba*; but he has also seen this Rotifer a prey to an *Amœba*.

VII.—In the foregoing remarks on the Rhizopoda, we have alluded to one of the simplest (*Protamœba*, Fig. 2), and to one of the most highly developed (*Amœba*, Figs. 1, 3), for the convenience of describing both the general and the essential characters of the sarcode elements belonging to the whole group. In entering on a description of the other special forms, it would be technically correct to begin with the simplest and to proceed to the more advanced. But, in the first place, it is best for general observers to have some notion of that Rhizopod (*Amœba*) most commonly met with. Secondly, the order of any natural group is little like a straight line, but far more resembles a network, or a reticulate series of rings touching each other, on account of passages and gradations among characters, features, and structures not essential to strict zoological distinction, but analogies only, or homologies, nevertheless striking and useful to the student in remembering tabulated arrangements. Thirdly, whilst internal organs cannot always be readily seen, the external visible character of shelled or shell-less, of skeleton or no skeleton, of long or short, thick or thin pseudopods, of creeping, swimming, or stationary habits, at once takes the attention of the amateur, and serves to direct him to the right family and order.

Several classifications have been suggested, mainly on the difference of general shape and of pseudopodial elongations, on the variations of ectosarc consistency, and difference of tests and skeletal supports. These plans have been noted and reviewed by Wallich, Leidy, Claus, and others. Dr. Wallich, however, has pointed out the grounds on which a really natural classification of the Rhizopoda should be founded, namely, on the absence or presence of what appear to be specially differentiated parts of the sarcode, such as the *nucleus* and the *contractile vesicle*. These structures, elementary as they are, he believes to be indications of progressive organisation, and, as such, to afford a good structural and physiological basis for grouping the allied creatures in zoological order. Thus, first, those which have neither a definite nucleus nor a contractile vesicle he terms *Herpennata* (creep-threads), such as the *Foraminifera* (hole-bearers), with calcareous shell, and the *Polycestina* (many baskets), with silicious skeleton; secondly, those which have a definite nucleus, but no contractile vesicle, are his *Protodermata* (first-skins), of which some have their skeleton of solid silicious spicules and rays (*Plagiacanthida*, *Acanthometrina*, *Thalassicollella*), and others have a silicious skeleton of tubular fibres (*Dictyochida*); thirdly, those Rhizopods which possess both the organs mentioned above form the highest group, viz., the *Proteina* (Proteus-like). These are divisible by their pseudopods being either (1) "monomorphous" (single-shape), or (2) "polymorphous" (many-shape). The former division are the *Actinophryna*; the latter are the *Amœbina*.

For the reasons above stated, using the word "Rhizopoda" for the whole group, we will take them in order, from the *Amœba* downwards, with little violence to Dr. Wallich's system, though

reversing it, through those most highly organised, with nucleus and special vesicle, to those that appear to have only a nucleus, and then to such as have neither.

Professor Schulze and Dr. Hertwig believe that they have discovered a nucleus in *Foraminifera*, and some of their examples, at first sight, are very striking. The presence, however, of other endoplasts in recent specimens, and the possible artificial production of nuclear bodies in sarcode by re-agents, still keep our doubts alive; and Dr. Wallich is not yet inclined to alter his views as conveyed in the foregoing sketch of his system.

VIII.—Beginning with *Amœba*, essentially the best-organised of the Rhizopods, we have *A. proteus* (Figs 1, 3). Its name was founded on Linné's catalogue of organic beings in the later editions of his "Systema Naturæ," and on the still earlier appellation of "the little Proteus,"* given by Rûsel, in 1755, to this animalcule long before its real nature was understood. It is also known as *princeps*, having this name in Ehrenberg's magnificent work on Infusoria, &c. It was referred to as *Proteus diffluens* by Müller in 1786; and this would have been an appropriate name for this changeably spreading creature, but "Proteus" had already been used generically for the little cave-dwelling amphibian of Adelsberg, and a new specific name was not wanted. See Dr. Leidy's concise and clear history of the nomenclature of this and other *Amœbe* in his "Fresh-water Rhizopods of North America."

There are several varieties of *A. proteus*, one of which Prof. P. Martin Duncan has observed to habitually form only blunt or short lumpy pseudopods, but to move flowingly along quickly, with constant change of form, between nearly globular and somewhat cylindrical shapes. In time it becomes quiescent and round; and after parting with some of its contents, chiefly relics of food, it becomes encysted, and then bursts, giving birth to crowds of young individuals.

Another kind keeps its general outline more persistently than the other, but still creeps flowingly until a change comes, when it puts forth pseudopodial processes, and roams freely about, but afterwards attains an hibernating or quiescent stage. Having been shut up awhile in a closed membrane, like the other, it ultimately swarms with zoospores inside, and then they escape through the breaking of the capsule.

In its different stages *A. proteus* has been seen to vary in size and shape from globular 0·2 millimètre across, through ovoid 0·3 by 0·15 millim., dendroid 0·5 by 0·4, palmate 0·5 by 0·35, radiate 0·2 and 0·5 by 0·4, and cylindroid 1 millimètre long. The largest observed by Dr. Leidy occupied a space of 0·6 by 0·2 and 0·35 millim.

IX.—One particular kind of *Amœba*, which always has a tufted and knob-like extremity to its food-carrying, coarsely granular hinder moiety, has been named *A. villosa* by Dr. G. C. Wallich, who has especially studied, described, and illustrated the life-history of this and many other species of these Protozoa. *A. proteus* sometimes has a collection of little knobs or blunt papillæ (pimples) on its hinder end (see Fig. 3); but this other *Amœba* has always a villose or hairy ball-like end, with a narrow neck-like connection to the body. It begins as a small circular hairy patch, and is apparently sticky and prehensile, being often clogged with dirt.

This *Amœba* does not use pseudopods so freely as *A. proteus*. It grows to a much larger size ($\frac{3}{16}$ -inch) than that species; but, as in that so in this, the end of the individual is a quiet rounding up and a sudden bursting, with the outcome of innumerable spherules or germinal spores.

X.—There is a closely related form, but larger, and even less inclined to exert pseudopods, using its villose end in moving like the tail-sucker of the leech. On account of its peculiarities, Dr. Leidy refers it to Greeff's *Pelomyxa*.†

XI.—An Amœban animal with permanent bundles of long cylindrical tubular filaments trailing from its hinder portion has the appropriate name of *Ouranomœba*.‡

XII.—*Deinamœba*§ is a name given by Leidy to a curious villose Amœban animalcule, about 0·2 millim. in diameter, which has the peculiarities (1) of having the body and the pseudopods sometimes papillose, sometimes bristling with minute, stiff, pointed filaments; (2) of having at times an enveloping layer of delicate, transparent, jelly-sarcode, itself covered with similar needle-like filaments; (3) of extreme variability of form, chiefly round, ovoid, and sub-cylindrical. "Indeed,

* *Proteus*, the changeable sea-god.

† Greek, *pelos*, mud; *myxa*, mucus.

‡ Greek, *oura*, a tail; *amœba*.

§ Greek, *deinos*, terrible; *amœba*.

no portions of the exterior of *Deinamæba* are constant, although they usually seem to be so. Head and tail appear to be mutually interchangeable; and such also is the case with the processes I have for convenience distinguished as pseudopods and papillæ.*

XIII.—F. E. Schulze's *Mastigamæba*† and the *Dactylospherium*‡ described by Hertwig and Lesser, are said by Leidy to have some resemblance to *Deinamæba*. But the former, about 1 millim. long, is broad, and tapering at the ends, with many pseudopods and a general investment of minute spiculate bodies, different from those of *Deinamæba*, and a long flagellum projecting in front from an ovate corpuscle, enclosing a nuclear body. (See Fig. 4.)

The latter has no flagellum, is irregularly round, 0·06 millim. in diameter, with somewhat conical blunt pseudopods in all directions; and one variety has minute villi of protoplasm, also differing from those of *Deinamæba*.

XIV.—*Podostoma*§ has relatively large pseudopods for locomotion, and others for feeding.

XV.—Among other Amœbians we may note *A. poly-poda*, found by Max S. Schultze in the lagoon-water at Venice. This is near *A. radiosa* of fresh water. His *A. porrecta*, from the Adriatic, differs from a true *Amœba* in its delicate and branching pseudopods. Wallich, however, has pointed out that here, and sometimes with *A. villosa*, the usual short thick pseudopods are replaced by the finer filaments characteristic of the Filose Amœbians; and that we must not draw too sharp a line in classification when only one, and that not an essential, feature is used for the basis in grouping.

XVI.—The Amœbian animalcules which we have already mentioned are members of the group known as the *Naked lobose Rhizopods*; and these are necessarily of the highest importance to the naturalist searching for explanations of the ways and means of all Rhizopoda; for, being transparent, or nearly so, they allow of a direct scrutiny into their internal organs (if their differentiated parts may be so termed), and such an insight to be got of their physiological functions as comparisons with other known organs and functions will enable us to make. There are other closely-allied Rhizopods with thick pseudopods, but they have delicate coats, tests, or shells, of various composition and structure, and yet for the most part not interfering with a direct acquaintance with the interior of the animal. They creep along with the aperture of the shell downwards, and the pseudopods, spreading out from it, attach themselves to the surface on which they crawl.

XVII.—Of these "Shelled Lobosa," the *Difflugia*|| is one of the most common kinds, and comprises many so-called species, which, however, together even with some allied genera, are probably only varieties of one typical form. The shell is very variable in shape and substance; globular, or oval, with or without a neck, like a balloon, an urn, an amphora, a pitcher, a vase, a broad-mouthed flask or bottle, with endless modifications; opening downwards at what is usually the narrow end; the base sometimes pointed, instead of being round or flat, and the sides occasionally armed with spikes; the shell in many cases oblique, one-sided, or otherwise asymmetrical, and even partially curved on itself, like a chemical retort, when, as Dr. Wallich has explained, the animal has adhered to some object under the influence of a current of water pushing it over to one side. Its composition is tough in tissue, like chitine; but it has been originally soft enough (or has had an occasional overcoat thrown back over it soft enough) to be encrusted with embedded sand, Diatoms, spicules, &c., sometimes neatly fitted together, or even arranged with a parallelism when the component Diatoms are large and long.

In allied forms (*Quadrula*, &c.) the envelope has hardened in segments on some geometrical plan, so that it is formed of little tablets, six-sided or square, edge to edge. Whether the tough test-matter is secreted by the ectosarc, or the latter becomes superficially consolidated, is not known.



FIG. 4.—MASTIGAMÆBA ASPERSA, AS SEEN CREEPING OVER THE FIELD OF THE MICROSCOPE.

An intermediate form between the Rhizopoda and the Flagellate Infusoria. Highly magnified (Copied from Allman, after Schulze.)

* Leidy, *Op. cit.*, p. 87.

† Greek, *dactylos*, a finger, or a date; *sphaîra*, a sphere or ball.

§ Greek, *pous*, a foot; *stoma*, a mouth.

† Greek, *mastix*, *mastigos*, a whip; *amœba*.

|| Latin, *diffluo*, I flow in different directions.

The sarcode almost fills the interior, and is attached inside by threads of ectosarc to the hollow sides and the base; and it stretches to the mouth, whence it sends out about half a dozen simple or branching pseudopods, and occasionally protrudes a large lump of its sarcode, usually soon retracted. The food is, of course, taken in by that aperture, and the effete remnants are ejected thence at the base of the pseudopods. Nucleus and contractile vesicle exist as in the naked *Lobosa*.

XVIII.—*Hyalosphenia** is much like *Diffugia*, but has a transparent, structureless, bag-like test, of a flattened-ovoid shape; and gives out only a few finger-like pseudopods.

XIX.—*Quadrula*† is a very delicate and neat *Diffugia*, with pear-shaped test, composed of thin square plates symmetrically arranged.

XX.—*Nebela* is another *Diffugian* genus well known in its many "species," having a pear-shaped, transparent, cancellated, membranous test, made up of circular, oval, narrow-rectangular, and narrow-angular plates, occasionally more or less invested with extraneous particles, and sometimes crested, hirsute, or spiked.

XXI.—*Heleopora*‡ is another closely related form, separated and named by Leidy because of certain peculiarities in its plating, in its taking on sand at its rounded base, and its numerous pseudopods.

XXII.—*Arcella*,§ one of the commonest of the shell-bearing *Rhizopods* found in fresh water, may be said to be like a flattish bell, a buckler, or a bun with a hole in its flat base, or a cap (Scotch "bonnet"), each liable to various symmetrical squeezings of the sides and margin; sometimes turned up, with sharp angles and long points. The shell is tough, not sandy, usually brown, and cancellated with a delicately minute hexagonal pitting. The edge of the aperture, which is large, is frequently turned inwards and upwards to some extent. The pseudopods are few and simple.

There is also a terrestrial *Arcella* (*A. arenaria*), described by Dr. Greeff.

XXIII.—*Centropyxis*|| is a common form, allied to *Arcella*, but not so symmetrical. Sub-globular and depressed, sometimes spiky. Aperture not in the middle. Test sandy, as in *Diffugia*. Pseudopods simple.

XXIV.—*Cochliopodium*¶ is a curious Amœban, putting on very enigmatical appearances according to its changes. It is bell-shaped, with a flexible test, sometimes expanding widely at the aperture, which contracts or enlarges as the margin is bent in or out. The sarcode fills up and adheres throughout to the inside of the envelope. Pseudopods delicate, sometimes forking.

The above and other shelled Amœbans live in fresh water.

XXV.—Another group of fresh-water *Rhizopods* are those having thread-like branching pseudopods (hence termed *Rhizopoda filosa*, or *R. filigera***), but otherwise the same general constitution and form as the Shelled Lobose species.

Their sarcode is generally like the endosarc of the *Lobosa*; the delicate "pseudopods appear as filaments of the finely granular protoplasmic basis of the sarcode;" and their branches seem to be only entangled in capturing prey, and not to blend or pass one into another. The tests are egg-shaped, or like bags or flasks, &c., similar to those of the *Lobosa*, but generally more delicate, and not so various in form, but always opening downwards, and sometimes excentric.

Pamphagus,†† *Euglypha*,‡‡ and *Trinema*§§ are some of the most common and best-known of the *Filosa*.

XXVI.—Both the naked and the shelled Amœbina (Leidy's *Protoplasta lobosa* and *P. filosa*) have their sarcodic contents encysted in a quiescent stage, the body having been purged of all effete matter; and the little globular mass ultimately breaks up into spherules, which are germs or spores in all probability. Dr. Leidy notes that "From the researches of Mr. Carter||| it would appear that in *Amœba* and *Euglypha*, representatives of the Lobose and the Filose Protoplasts, the endosarc becomes resolved into nucleated cells, which are of the nature of ova; while the nucleus is resolved into granulariferous, non-nucleated cells, finally breaking up into their constituent granules, which are of the nature of spermatozooids."¶¶

* Greek, *hyalos*, crystal; *sphen*, a wedge.

† Latin, diminutive of *quadrus*, square.

‡ Greek, *helos*-(cos) a bog; *pera*, a bag.

§ Latin, *arca*, a box.

|| Greek, *centron*, a prickle; *pyxis*, a box.

¶ Greek, *cochlos*, a shell-fish with spiral shell; *pous*, a foot.

** Latin, *filum*, a thread; *gero*, I bear.

†† Greek, *pamphagos*, all-devouring.

‡‡ Greek, *eu*, well; *glyphe*, sculpture.

§§ Greek, *tri*, three; *nema*, thread.

|| "Annals and Magazine of Nat. Hist.," 1856, vol. xviii., p. 226.

¶¶ Greek, *sperma*, seed; *zoön*, an animal; *eidos*, appearance.

XXVII.—Another kind of Rhizopod, also inhabiting fresh water like the foregoing, are the Sun-animalcules, or *Heliozoa*.^{*} These, however, float free in the water, and have round bodies, with delicate pseudopods radiating from all parts of the surface, producing a very gentle gliding movement, and serving to capture prey. The sarcode in these animalcules has usually a yellowish tint, and contains many clear globules or water-cavities, giving it a foamy appearance. Sometimes it is green with either granular or diffused chlorophyll, derived from minute *Algae* taken in as food. There are often red spots, also due to *Algae*. Besides one or more nuclei, there is a conspicuous contractile or pulsating vesicle (sometimes more than one); and this in its action rises like a bubble above the level of the surface, in some species, and bursts so violently, as to shake the whole animal and to make the discharge of its contents evident in the surrounding water.

Their body often presents the appearance of a central granular mass, enclosed in a capsule, but this is much more evident in some of the allied marine *Radiolaria*.[†] The pseudopodia are thin threads of granular protoplasm, tapering to extremely fine filaments, rarely forked or branching at the ends. Though straight, they are not rigid, but flexible and contractile, drawing the food-atoms they touch towards the body, where the particles are enveloped by the sarcode and taken inside. In some cases the pseudopods are said to be strengthened by an internal axis of tougher material. Sometimes the animalcule seems to stand, as it were, on the ends of the pseudopods touching the object beneath.

Most of the *Heliozoa* are soft and naked; but others have an extremely rudimentary skeleton of silicious[‡] spicules in the outer layer of sarcode; and some have a more developed and delicate shell, of the same mineral substance, like lattice-work, forming an elegant trellised sphere.

This group corresponds to some extent with the marine *Radiolaria*, and is termed "Fresh-water Radiolarians" by some; but they have a greater simplicity of constitution than most of the former.

XXVIII.—*Actinophrys sol* (Fig. 5), "the common Sun-animalcule, is one of the most familiar and striking forms of microscopic life of still fresh water. . . . It may be found in almost every standing water-pool, pond, or lake, swimming among aquatic plants; its favourite haunts being duck-meat, hornwort, bladderwort, or the various filamentous *Algae*. It commonly appears as a globular hyaline, foamy, or vesicular body, bristling with delicate rays, and suspended almost stationary in the water." (Leidy.) It is about $\frac{1}{12}$ th millimetre in size, and feeds on Rotifers, Infusoria, unicellular *Algae*, and Zoospores. Active animalcules touching its rays often seem to be paralysed. Small prey glides down the pseudopods to their roots, where sarcode protrudes and takes it in. Dr. Wallich, in one of his memoirs, has figured an *Actinophrys* becoming itself a prey to a large *Amoeba*, which tore it piecemeal by means of its pseudopods, and engulfed a moiety of it lump after lump. In his description of this circumstance, that careful naturalist remarks that, however successful the stolid energy of the *Actinophrys* usually may be, yet when an *Amoeba* comes to the front the former avoids it; but the latter with unusual activity endeavours to seize and to envelope, or at least to tear out portions of the *Actinophrys*.

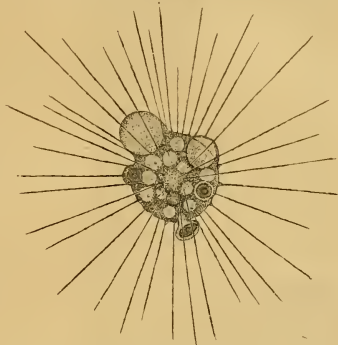


Fig. 5.—*ACTINOPHRYS SOL*.

The light spots are vesicles and water-cavities. The projecting globule is a contractile vesicle about to burst. The dark spots are green zoospores of *Algae*, taken in as food. The pseudopods are here made much too thick. Magnified 500 diameters. (After Leidy.)

^{*} Greek, *helios*, the sun; *zoön*, an animal.

[†] Latin, *radiolus* (diminutive of *radius*), a little staff or rod.

[‡] Latin, *silex*, quartz or flint; used for the kind of mineral comprising both these and other varieties of *silica*.

[§] Greek, *actis*, a ray; *ophrys*, the eyebrow.

XXIX.—*Heterophrys** has an external villose or velvety layer of sarcode.

XXX.—*Raphidiophrys*† is an Actinophryn with a thick external layer of delicate sarcode, which is full of minute silicious(?) spicules, and extends for some way along the pseudopods.

XXXI.—*Vampyrella*,‡ an animalcule not yet well understood; by some regarded as an Actinophrys, capable of Amœban variations of form, and making finger-like, lobate, and wave-like expansions of its sarcode. The presence of a nucleus is doubtful; and one marine form, having no nucleus, is placed by Haeckel among his *Monera*. The fresh-water *Vampyrella* feeds on the cells of the little Alga called *Spirogyra*. Creeping on a filament, it perforates cell after cell, transferring the contents to its own interior. The marine *Vampyrella*, in like manner, feeds on the *Gomphonema*.

XXXII.—*Diplophrys*§ is very minute, associated in groups while young, but isolated when full grown; it then has a delicate envelope which permits of the extrusion of only two tufts of attenuated pseudopods.

XXXIII.—*Actinosphaerium*|| is larger than the Sun-animalcule, sometimes 0·4 millimètre in diameter; it looks much like it, and its habits are very similar, but it is rarer, and the outer or clear vesicular portion is very distinct from the interior clouded, though still vesicular mass. The pseudopods are more distinctly strengthened by a stiffer internal axis than in *Actinophrys*; and yet the pseudopods can be retracted; and sometimes they wholly disappear.

XXXIV.—*Acanthocystis*¶ is like an *Actinophrys*; but it has in some cases an external coat of delicate protoplasm, full of exceedingly fine spicules (as in *Raphidiophrys*); and also, besides thin pseudopods all over the surface, it has numerous long silicious spicules or rays, often forked at the end, standing out from every part of the body.

XXXV.—*Hyalolampe*** has a body invested with minute, clear, silicious globules.

XXXVI.—*Clathrulina*†† has an Actinophryn body invested with an elegant, globular, silicious trellis, through which the pseudopodal rays project; and this spherical latticed or fenestrated‡‡ capsule is attached by a long, thin, silicious stem or "pedicle" to water-plants (Fig. 6). Young individuals without the lattice skeleton rise from, and are attached to, the old ones. Adult forms, however, have been seen which have divided, within the skeleton, into two or four parts, each of which became encysted, and ultimately gave birth to a minute, nucleated, swimming atom; and this by-and-by became furnished with a trellis-coat and a fixed pedicle.

XXXVII.—*Zooteca*§§ is also an Actinophryn with contractile pointed filaments, and elevated on a pedicle; but this is contractile, and not silicious; and there is no skeleton.

XXXVIII.—Besides the *Heliozoa*, the *Radiolaria* comprise other kinds of Rhizopods. These are marine, floating at or near the surface of the sea. Most have silicious frameworks; and their bodies are often of bright colours (yellow, red, violet, and blue, especially), either in spots or diffused generally. One set (*Plagiacanthus*|||) have their sarcodic body divisible into a clear, toughish

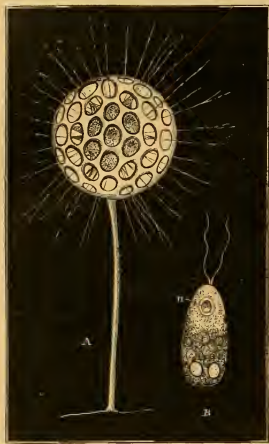


Fig. 6.—CLATHRULINA ELEGANS.

A, Completely developed; magnified more than 300 diameters; B, a zoospore, or "Swarm-spore," with two flagella; C, a nucleus (n), and several contractile vesicles (white spots). Very highly magnified. (Copied from Altmann, after (A) Greeff and (B) Haeckel and Lesser.)

* Greek, *heteros*, diverse; *ophrys*, an eyebrow.

† From "Vampyre."

‡ Greek, *diploos*, double; *ophrys*, an eyebrow.

¶ Greek, *acantha*, a thorn; *cystis*, a pouch.

†† Latin, *clathri*, a lattice.

||| Greek, *plagios*, oblique or transverse; *acantha*, a thorn or spine.

‡ Greek, *raphis* (—*idos*), a needle; *ophrys*, an eyebrow.

| Greek, *actis*, a ray; *sphaيرا*, a sphere.

** Greek, *hyalos*, crystal; *lampe*, foam.

‡‡ Latin, *fenestra*, a window.

§§ Greek, *zoe*, life; *teiro*, I rub.

ectosarc and a granular and highly-coloured endosarc (sometimes bright red), enclosing a large central body with a membranous envelope.

Vacuoles, and many minute yellow bodies—the latter defined by Wallich as “sarcoblasts,”—such as occur in very many other Rhizopods, and serve as their ovules, are also present; and there is the usual kind of protoplasmic circulation. In many forms there is a silicious skeleton, either of interlacing spicules, or of connected rods and meshes, or a perforated spherule, constituting, under various modifications, exquisitely beautiful crystal basket-work, lattices, or trellises, surpassing even the perforated, ivory-nested capsules of the neatest and most elaborate Chinese carving. In this character of silicious basket-work, they resemble those Radiolarians which possess no nucleus or contractile vesicle, and are specially known as *Polyceistina*. *

XXXIX.—Of the Plagiacanth, as defined by Dr. Wallich, the *Acanthometra*† (Fig. 7) heads a numerous and important group. *Xiphacantha*‡ (Fig. 8) is one of them, and has a silicious skeleton of twenty long, sharp, regular, radiating rods or prickles, the bases of which fit neatly together in the central capsular body. Just within the surface of the body, and parallel to it, each gives off symmetrical cruciform branches, which constitute altogether an open spheroidal lattice-work.

XL.—*Stylodictya*§ (Fig. 9) belongs to a series of more or less discoidal forms, composed of two parallel, perforated, or reticulate plates, coalescing round the margin (from which spines project at regular distances), and separated elsewhere by an intermediate series of concentric or spiral rings.

XLI.—*Thalassicolla*|| is one of the marine nucleated Radiolarians without a skeleton. *Acanthodesma*,¶ an allied form, has a loose network of spicules for a skeleton; and, in other forms belonging to this group, there are various modifications of rods and rays.

XLII.—In the *Collosphæra*** and in *Sphærozoum*,†† numerous minute nucleate individuals are associated in a relatively large gelatinous mass. In the latter species, each zoëd has silicious spicules, but in the former each has a simple perforated or fenestrated spherical skeleton.

XLIII.—Artificially arranged among the *Radiolaria*, on account of the structure of their skeleton, are the *Polyceistina*; but Dr. Wallich recognises in them neither central nucleus nor any contractile vesicle, sarcodæ not differentiated into endosarc and ectosarc, some vacuoles, the pseudopods frequently anastomosing, and showing the usual kind of circulation. Their silicious skeleton, generally globular, is variously trellised, and sometimes composed of two, or even three, concentric basket-balls, supported and separated by few or many long radiating spicules, passing from the centre to beyond the surface. These rays commence from a central base (“omphalostyle”‡‡ of Wallich), either symmetrical in a spherical chamber, in his “*Cyclolina*” (circular), with *Haliomma*,§§ *Amphidiscus*,||| and *Astronma*¶¶ for types, or asymmetrically, as in his “*Monodina*” (single), with *Podocerytis* for their type.

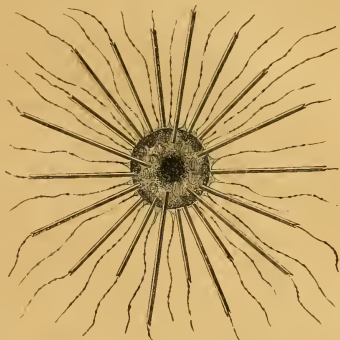


Fig. 7.—ACANTHOMETRA ECHINOIDES.
Highly magnified. (After Claparede and Lachmann.)

* Greek, *polys*, many; *ciste*, a box.

† Greek, *xiphos*, a sword; *acantha*, a thorn.

|| Greek, *thalassa*, the sea; *colla*, glue, jelly.

** Greek, *colla*, jelly; *sphaïra*, a sphere.

†† Greek, *omphalos*, a navel; *stylos*, a column.

||| Greek, *amphi*, round-about; *discos*, a quoit.

† Greek, *acantha*, a thorn; *metron*, a measure.

§ Greek, *stylos*, a column; *diktynon*, a net.

¶ Greek, *acantha*, a thorn; *desmos*, a chain.

†† Greek, *sphaïra*; *zoön*, an animal.

§§ Greek, *hals*, the sea; *omma*, an eye.

¶¶ Greek, *astron*, a star; *omma*, an eye.

*Podocyrthis** (Fig. 10) has a fenestrated, casque-like skeleton, globular where largest, then tapering, and then spiked, at one end; and open, with three marginal prickles, at the other.

Eucyrtidium† (Fig. 11) is a Polycistine, with a nearly conical reticulate skeleton, somewhat like a high-peaked Indian helmet of chain-mail.

Euceryphalus‡ (Fig. 12) has a beautiful umbrella-shaped lattice as a protection to its soft vesicular body.

The *Polycistina* are enveloped in a delicate fibry investment of sarcode, when alive; and their sarcode-blasts or ovules are abundant. However complex the skeleton may seem to be in any of these Radiolarian forms, we must recollect that it is a feature of less essential value in biological classification than the internal organs. Therefore the *Polycistina* are low in the scale (just below the nucleated Radiolarians); and, unless a "nucleus" should be decidedly found in the *Foraminifera*,§ these latter come last of all, among the interesting and great family of Rhizopoda.

XLIV.—In the last-mentioned group we find the pseudopodia branching out and blending one with another, and thus forming a mesh-work or reticulation. Hence the *Foraminifera* have been placed among the *Reticularia*,|| whenever the pseudopods have been taken for chief guidance in grouping the forms. Some of the *Polycistina* have a tendency to this habit.

One kind of Reticulose Rhizopods (*Lieberkühnia*) has neither nucleus nor contractile vesicle, and is therefore very low in the scale of being; others (*Biomyxa* and *Gromia*) have both these endoplasts, or protoplasmic organs, and therefore rank as high as the Amœbans. As to their habits, some genera have representatives in both fresh and salt water (*Gromia* and *Lieberkühnia*), some only in fresh water (*Biomyxa*), some only in salt and brackish water (*Foraminifera*).

The *Reticularia*, or Reticulose Rhizopods, protrude many long thread-like pseudopods, which

* Greek, *pous*, a foot; *cyrtē*, a fish-basket.

† Greek, *eu*, good; *cyrtē*.

‡ Greek, *eu*, good; *ceryphalos*, a hair-net.

§ Latin, *foramen* (*foraminis*), a hole; *fero*, I bear. This name was given to them originally, not on account of the superficial perforations, but because their dividing walls have one or more simple holes; and these were thought to constitute a distinction from the tubed apertures in the divisions of the cephalopodous shells with which they were then confounded.

|| Latin, *reticulum*, a little net or a network.

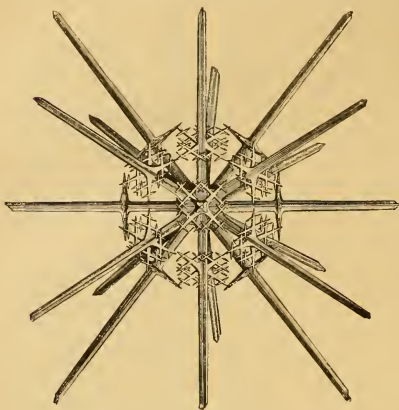
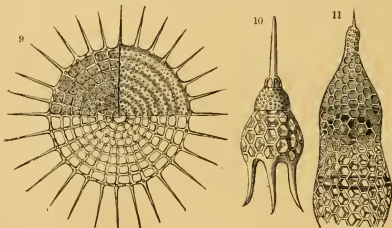


Fig. 8.—XIPHACANTHA MURRAYANA. (After W. Thomson.)
The skeleton of a Radiolarian of the *Acanthometra* type. Magnified 100 times



Figs. 9, 10, 11.—RADIOLARIAN SKELETONS, OR LATTICED SILICIOUS SHELLS. Highly magnified. (After Haeckel.)

Fig. 9, *Stylocyrtus multispinus* (Haeckel), living off Messina; Fig. 10, *Podocyrthis schomburgkii* (Ehrenberg), fossil from Barbadoes; Fig. 11, *Eucyrtidium Jogenum* (Haeckel), living off Messina.

frequently blend together here and there, away from the body, or "anastomose" among themselves so as to form irregular meshes of sarcode. Some of these animalcules possess the important "nucleus" (*Shepherdella*, Siddall), and one or more "contractile vesicles" (*Biomyxa*, Leidy; and *Gromia*, according to Wallich). Among the Foraminifera, some are said to have yielded evidence of the presence of a "nucleus." But it is possible that these apparently nuclear bodies are "sarcoblasts," either isolated or in groups, especially when the granular forms have come to light by the intervention of re-agents.

In effect, fresh specimens show nearly clear and quite pale "nuclei," or none at all; and those subjected to re-agents show granular bodies, like "nuclei," pale or darkish, and sometimes with a central spot, either dark or pale. In the first case, the presence of definite globular bodies, besides *nuclei*, in Rhizopods, must be thought of; and, in the second case, the effect of chemical re-agents on the (1) sarcodic granules, and (2) on the endoplasts (sarcoblasts) in Rhizopods, must be allowed for before the above-mentioned corpuscles in certain *Miliolæ* and *Planorbulinæ* (?) can be regarded as true *nuclei*.

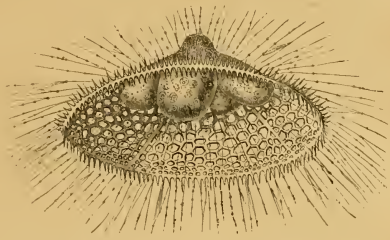


Fig. 12.—*EUCECRYPHALUS SCHULTZEI*.
A living Radiolarian of the Cyrtidan family; off Messina. Highly magnified. (After Haeckel.) This is tipped up a little, so as to show the body with its sarcoblasts inside.

XLV.—*Lieberkühnia** is a simple, granular, non-nucleated, thin-skinned Rhizopod, with vacuoles. It is egg-shaped, and sends off from one part of its body a stem-like process, at first within a filmy coating of the general sarcode, but soon branching off again and again into finer and finer filaments. These coalesce freely, and form islets here and there among the shifting and changing reticulations. The granules of the protoplasm have the usual circulatory movement, somewhat like that visible in *Valisneria*, *Nitella*, and other plants, but of a different physiological character, not being so regular, and evidently more dependent on the actual movements of the animal. This rare animalcule was first described and figured by Claparède and Lachman in their "Les Infusoires et les Rhizopodes." Mr. Siddall found it in sea-water.

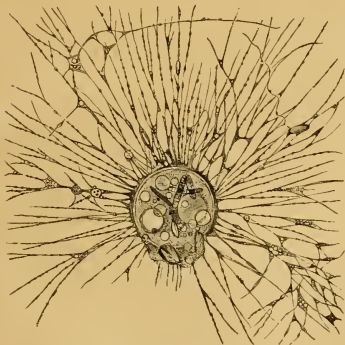


Fig. 13.—*GROMIA TERRICOLA*.

Animalcule with a filmy coat of sarcode and extended, interlacing, and reticulate pseudopods. The transparent envelope shows a large nucleus, vacuoles, oil-globules, and food within. Sand and dirt adhere at the hinder end (below). Magnified 20 diameters. (After Leidy.)

sends off numerous attenuated and anastomosing† pseudopods. Granular "circulation" is seen in

* *Lieberkühn*, a famous microscopist.

† Greek, *ana*, through, *stomoo*, I furnish with a mouth, I open. Applied originally to the junction of veins and tubules, whereby they open one into another.

+ Greek, *bios*, life; *myxa*, mucus.

the sarcode of the body and the filaments. Blended portions of the latter, seemingly detached by accident, continue to exist as non-nucleated Rhizopodous organisms.

XLVII.—*Gromia*, discovered by Dujardin in both salt and fresh water, is a round or egg-shaped little mass of granular sarcode, with relatively large central nucleus, vacuoles, contractile vesicle (seen by Wallich), and a tough membranous investment. The last is thin, transparent, and usually open at one end only, whence the sarcode is extruded. This stretches forth in thin branching pseudopods, and also extends itself as a film back over the whole of the test, giving off long delicate pseudopods from its general surface. These are continually changing in direction and extent, uniting and disuniting among themselves, or moving as lashes, spirals, and otherwise. At their unions they form islets of sarcode, which become the centres of secondary nets.

A very interesting kind of *Gromia* (Fig. 13), found by Dr. Leidy among the damp moss of his house-yard in Philadelphia, is named by him *G. terricola*. It is about twelve millem. in diameter; and with its pseudopodial net fully spread, this *Gromia* looks somewhat like a spider in its web. Its food consists of "minute Diatoms, fragments of *Lyngbya*, and globular green Algae." It takes in some sand also.

XLVIII.—Many of the Reticularian Rhizopods have a calcareous shell, not a merely spicular or fibrous, basket-like skeleton, like a Radiolarian silicious framework, but composed of definite chambers or compartments, sometimes one, often more, in regular sequence on a straight line, or bent, coiled, alternating, concentric, or even irregularly heaped, in almost endless modifications. These lime-made shells are thus either simple or compound, containing—(1) only one round, oval, or elongate morsel of sarcode; or (2) more than one, sometimes very many such little bodies in one shell, which is chambered or divided according to the number of segments of sarcode constituting the whole animalcule.

On account of this latter condition, these calcareous-shelled *Reticularia* have been termed *Polythalamia*.^{*} The first-mentioned, or single-chambered ("monothalamous") condition, whether regarded as a special form, or as an exception to the general rule, being due either to immature, imperfect, or varietal growth, at all events vitiates the application of "Polythalamia" to the whole of the group.

The walls separating the chambers of the compound shells are pierced with either one or many holes, for the passage of a thread ("stolon†") or threads of sarcode, by which the segments are connected together, and by which, indeed, each new segment stretches, buds, or grows out from the older portion of sarcode. These simple holes in each separating wall ("septum‡") of the chambers in those of the compound shells which look like little Ammonites and Nautiluses were at first thought to constitute a distinction between those high-class Molluses which have tubes ("siphons" or "siphuncles") from chamber to chamber, and these minute shells, which were at that time mistakenly referred to that class; and thus they were called *Cephalopoda foraminifera*, to distinguish them from the *Cephalopoda siphonifera*. Although this mistake was soon corrected, the word Foraminifera has been kept for these Reticularians under notice.

Some wrongly think that the name is due to the fact that in many instances the whole of the outside shell is perforated with either small holes or minute tubules. In this latter sense, however, the name would not be applicable to the whole of the group; for in a large and important division the general shell is not pierced with any holes, but has solid walls except at the single aperture whence the sarcode pushes out an external filmy coat and pseudopods, or buds out on a new stolon (Fig. 14).

Hence *Foraminifera* are divisible into two main groups:—1. The imperforate (*imperforata*), or porcellanous (*porcellana*); 2. The perforate (*perforata*), or glassy or vitreous (*vitrea*, also *hyalina*). on account of their relative translucency. There is also an intermediate group, called the arenaceous, or sandy (*arenacea*), some of which seem to belong to the one, and some to the other of the foregoing divisions.

Still there are even in these groups, however distinct they may appear to be at first sight, links

^{*} Greek, *polys*, many; *thalamos*, bed or chamber.

† Latin, *stolo* is used by botanists for a kind of root: from Greek, *stolos*, a setting-out or a source.

‡ Latin, *septum*, a hedge or wall.

of alliance (besides their pseudopodial and physiological characters), as well as exceptions in their structural characters; for (1) some individuals of the porcellaneous one-mouthed kind have connecting passages between their inner chambers; (2) some of the perforate forms begin with the usual hyaline shell-structure, but become coarse, imperforate, and sandy with advancing age. (3) Moreover, some of the smooth *porcellana* become sandy as they grow. (4) Some, also, of the same kind secrete little or no shell-matter, and have sometimes merely a covering of membranous consistence, like that of some of the shelled *Amœbans*, many of which latter group we may remark, though they are not calcareous, have the habit of taking up sand to stiffen their tests. (5) Some of the arenaceous kinds send out pseudopods from between the sand-grains embedded, but not cemented, on their surface, and do not appear to have the usual large aperture for the stolon; and there is said to be even a simpler kind, merely a little morsel of sarcode containing sand, not as a coating, but mixed up vaguely with it,* more abundantly, it seems, than the grains of sand found in some of the more glutinous and coarse-feeding of the *Amœba*, and serving perhaps to give a kind of general stability to the little Moneral organism. The largest known of the *Arenacea* are *Parkeria* (after W. K. Parker), and *Loftusia* (after W. K. Loftus).

Those *Foraminifera* which have a white, opaque or compact, non-porous, porcellaneous shell, without perforations for the passage of pseudopods from every part of the enclosed body, comprise six well-known typical forms. Around these an almost endless series of more or less allied forms, having the same essential characters, but varying in modes of growth, and often almost imitating one another, especially in their young stages, may be grouped by zoologists. There is, first, the *Cornuspira* (horn-coil, Fig. 16.), a simple thread of sarcode coiling flatwise, and coated with the usual opaque shell open at the end. Becoming constricted at intervals, and losing its circularity, it seems, if we put all the varying individuals in a series, to pass into a *Miliola* (millet-seed), which is folded up and down, and is pinched in at the turns—whether these come exactly opposite to each other on the two sides of the shell, as in *Biloculina* (two-chambers) and *Spiroloculina* (spiral chambers, Fig. 16.); or do not equally match on opposite sides, but leave three or five folds visible on the unequal faces, as in *Triloculina* and *Quinqueloculina* (three and five chambers, Figs. 14, 16.). Some individuals when young, and even in the adult state, make but an imperfect second chamber in the turn of the shell; and, beginning like the retort-shaped *Diffugia*, seem to fail in advanced growth, as the *Adeloxina* (not manifest, or uncertain). The *Miliolides* may be said to be cosmopolites, in all seas; and they are frequent in a fossil state, especially at Paris. Again, some begin with the circular, or with the alternate or agathistegian (ball-of-thread-like) folds,

but go off with a straight growth, chamber after chamber—sometimes narrow, as *Articulina* (joint-like), or broader as in *Vertebrulina* (vertebra-like), common in the Red Sea. In all these the terminal aperture, whatever its relative size may be, gives out the sarcode to make pseudopods, but not to go back over the whole shell as a coating film.

Another kind of shell among the porcellaneous group has often a delicate pearly whiteness; and begins with one globule of sarcode, which gives off by one stolon a half-moon-shaped segment, which, in its turn, gives off two or more stolons, and a larger, curved, narrow segment; and this produces a transversely-longer crescentic addition with additional parallel and advancing stolons, until chamber after chamber lengthens and widens the shell in its growth, often curving elegantly (on a plane). It is pierced at its terminal edge either with separate holes or a branching rift (as if the holes had run one into another); and thus we have the *Peneroplis* (a fancy name), with perforate edge, or *Dendritina* (Fig. 30), with "tree-like" mouth. Often *Peneroplis* grows quite narrow and straight after a feeble youth of spiral growth, and then it is like a crozier. It is common in the Red Sea and Mediterranean.

Orbiculina (circle-like) is formed on somewhat the same plan, but it is not so pearly, and from



Fig. 14.—*MILIOLA* (QUINQUELOCULINA).

One of the "Porcellaneous" *Foraminifera* living. (After Schultze.)

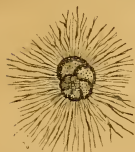


Fig. 15.—*DISCORBULINA*. (After Schultze.)

One of the "Vitrescens" *Foraminifera* living.

* Carpenter, "Foraminifera," *Encycl. Brit.* ix., p. 375.

the first it sets on its new segments as nearly complete rings, close and neat, and with the sarcode even branching upwards into overlying rings, so as to thicken the early portion of the shell. But whether the flat compound shell is ear-shaped, and shows a delicate concentric spire on its faces, or is discoidal, with rings almost truly concentric, its sarcode only comes out at the marginal pores of the last "annuli" (rings) of the shell, which, like the earlier narrow curved chambers, are usually (not always) subdivided in a uniform manner, corresponding to the external openings. These are abundant in the West Indies and elsewhere. *Alveolina* is, as it were, an *Orbiculina* rolled up on a long transverse axis. They are fossil and recent.

Orbitolites, truly concentric from its first growth, has larger chambers (segments of sarcode) than *Orbiculina*, though some of the two kinds are distinguishable with difficulty; it is also more free

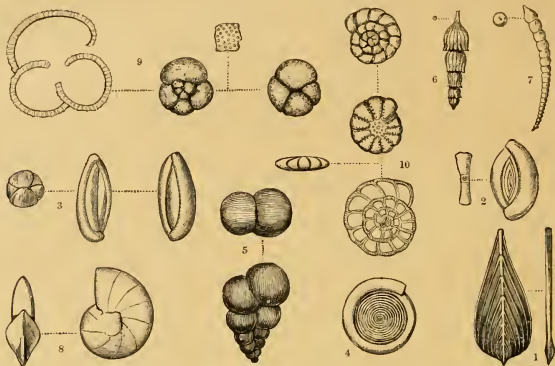


Fig. 16.—VARIOUS FORMS OF FORAMINIFERA.

1, *Frondicularia goldfussi*, Reuss, Cretaceous, Bohemia. 2, *Spiroloculina badensis*, d'Orbigny, Miocene, Baden, Vienna. 3, *Quinqueloculina saxorum*, Lamarck, Eocene, Paris. 4, *Cornuspira polyzyra*, Reuss, Oligocene, Hungary. 5, *Textularia globifera*, Reuss (striata, Ehrenberg), Upper Cretaceous, Traustein. 6, *Nodosaria spinicosta*, d'Orbigny, Miocene, Vienna. 7, *Dentalina elegans*, d'Orbigny, Miocene, Vienna. 8, *Cristellaria rotulata*, Lamarck, Cretaceous, Bohemia. 9, *Globigirina conglomerata*, Schröter, Pliocene, Kar-Nikolar. 10, *Rotalia beccarii*, Lamarck, Pliocene, Sienna.—(Copied from Zittel, after Reuss and others.)

to grow thick in its outer rings. Each annulus is formed by the coalescence of the peripheral crop of buds, with a new stolon going off from between each pair of these new segments. This is famous as being one of the common fossil Foraminifera of the white friable limestone near Paris and elsewhere in N.W. France. It lives in the Australian seas, and thrives at Fiji and elsewhere.

An immense variety of forms can be grouped, according to more or less striking alliances, round the *Lituola* (little crozier), which is essentially an arenaceous Foraminifer, but has some allies, which, without losing touch of *Lituola* in some resemblance or other, are as porcellaneous as *Miliola*, and others which, except for their sandiness, would belong to the hyaline or vitreous group.

Trochammina (wheel sand), fossil and recent, is usually a simple, flat-coiled shell, looking like smooth sandy plaster. But it may be otherwise twisted, and constricted at intervals. Thus one kind is called *T. gordialis* (Gordian knot); and another imitates a *Rotalia*. *Endothyra* (inside door), abounding in some Carboniferous strata in various parts of the world, is arenaceous, and of many forms. So also *Valutina* (valve) and *Textularia* (plaited, Figs. 16, 25, 26), are sandy, but only with advancing growth. They have an alternate arrangement of chambers, but on different plans. Both also often grow on with a straight or linear set of chambers, as *Bigenerina* (double-kind, Figs. 27, 28,—a variety of *Textularia*). *Bulimina* (bulinus-like, Fig. 32), with an alternate growth,

but differing from the last both as to its aperture and its segmental plan, also becomes sandy in old age. The last three kinds are known both recent and fossil.

The truly hyaline *Foraminifera*, with very small perforations of shell, have the one-chambered *Lagena* (flask) for their simplest type. This is often most exquisitely delicate and elegant. In *Glandulina* (acorn-like, Figs. 21, 22) and *Nodosaria* (knotty, Figs. 16_a, 23, 24) we see a series of chambers planned on the growth of successive *Lagena*, the base of the new one partly enveloping the front of the last segment. The ornaments are various, but chiefly thin ribs and delicate points. If not circular in section, but flat, the same kind of growth produces *Lingulina* (tongue) and *Fronicularia* (leaf, Fig. 16_i). If round in section, but bent, it is *Dentalina* (tooth, Fig. 16_j). Still further curved, whether thick or thin, convex or flat, smooth or ornamented, this kind of Foraminifer becomes a *Vaginulina* (sheath), a *Marginulina* (margin), and in the extreme a *Cristellaria* (crest, Fig. 16_s). If the segments grow alternate, we have either *Polymorphina* (many-shape) or *Uvigerina* (grape-bearer, Fig. 33). The last is not so common as the others of the *Lagena*-type, which abound both recent and fossil. Another set of hyaline Foraminifers has coarser pseudopodial passages through the shell, and more globular chambers, and these are set on in a somewhat heaped fashion, and but roughly spiral, so that in most cases the stolon-hole of each chamber comes near to the other apertures, and they all open into a kind of vestibule in the middle of the shell. These are the



Figs. 21-24.—FORAMINIFERAL SHELLS (After d'Orbigny), FIGURED WITH THE APERTURE DOWNWARDS.

21, 22, *Glandulina levigata*, outside and section;
23, 24, *Nodosaria lamellosa*, outside and section.

it is like *bulloides*, but with enormously long, hair-like prickles; these in life are invested with sarcode, which, on the outside, becomes coated with shell in *Orbulina* (globe).

The *Rotalia* (wheel, Figs. 16_{oo}, 34) is a type, or leading form, among an immense series of more or less spiral Foraminifers, varying in their shell-structure plan of spire from nearly top-shaped to flat (with occasional loss of spire in either a cylindrical or a heaped growth), and the shape and position of aperture. *Pulvinulina* (cushion), *Discorbina* (basket), *Planorbulina* (flat-circle, Fig. 29), and *Calcarina* (spur, Fig. 31), are other important members of the Rotaline group.

Under the heading *Nummulitidae* are grouped some high-class Foraminifera, which, however, have their simple types among them and closely associated. Thus the little, thin, neat *Nonionina* (from "nonion," a fancy name) leads up, by more and more complex shell-structure, to *Polystomella* (many-mouth); and the relatively simple *Operculina* (like the operculum of some gasteropods) is at the root not only of the greater and complex *Nummulites* (coin-like), but also of its congeners—on one hand, *Amphistegina* (double-stage, Fig. 18), and, on the other, the more cyclical *Heterostegina* (odd-stage, Fig. 17), with *Cyclocypers* (circle-shield) and *Orbitoides* (circle-like). Most of the Nummulitids, except *Orbitoides*, occur abundantly in some sea or other. *Nummulites* is not rare, though small, in the Australian seas; but in the fossil state it constitutes masses of limestone, hundreds of feet thick, and hundreds of square miles in extent. Of these limestones many great



Figs. 17-20.—FORAMINIFERAL SHELLS. (After d'Orbigny.)

17, *Heterostegina depressa*; 18, *Amphistegina lessonae*; 19, *Pulvinaria discobolus*, one of the *Mitoides*; 20, *Orbitulites nummulitoides*, var. *subtus*.



Figs. 25-28.—FORAMINIFERAL SHELLS (After d'Orbigny), FIGURED WITH THE APERTURE DOWNWARDS.

25, 26, *Textularia aculeata*, outside and section; 27, 28, *Eugegerina* (*Textularia*) *nodosaria*, outside and section.

buildings have been constructed—such as the Cathedral of Gerona and some of the Pyramids of Egypt. *Fusulina* (distaff) is a spindle-shaped Nummulitid forming masses of limestone of Carboniferous age in Russia and North America. This form, *Alveolina*, and *Loftusia*, resembling one another in shape, belong to quite different groups; an example of the imperfection of d'Orbigny's classification based on the shape of shell and setting on of the chambers.

In many of the Foraminifera, especially the *Porcellana*, the chamber-walls merely tent over the sarcode, whether thread-like, beaded, folded, or spiral; the edges of the new chamber resting on the surface either of the object to which the Foraminifer is attached, or on a former whorl of the shell. In more highly-developed *hyaline* species, each segment of sarcode becomes wholly coated with perforated shell-matter, except where it is attached by the stolon to the previous segment, and where it gives off a new bud. Further, the sarcode is thrown back over the already formed chambers more or less freely, and the test gets thickened, and sometimes ornamented with supplemental shell-growth. But a most important feature in the best kind of these shells (*Nummulites*, *Polystomella*, *Rotalia*, *Calceolina*, &c.) consists of a system of vessels, or canals, formed between the consecutive chambers of such well-coated kinds, and continued in a spiral manner along the upper and lower edges of the chambers, and communicating either directly with the surface (*Polystomella*), or through a reticulation of similar vessels in the thickened edge or "marginal cord" of



Figs. 29-33.—FORAMINIFERAL SHELLS.
(After d'Orbigny.)

29, *Planorbulina mediterranea*; 30, *Peneroplus (Dendritina) arbuscula*; 31, *Calceolina defranci*; 32, *Bulimina marginata*; 33, *Cyprina pygmaea*. Figs. 29, 32, 33 are figured with the aperture downwards.

the shell. These vascular portions have been termed the "intermediate skeleton," with its "canal-system," and evidently permit of free sarcode communication between the early innermost segments and the outside (Fig. 34).

It is very doubtful to some if the *Foraminifera* and the marine *Radiolaria* use their pseudopods for catching living prey; and it has been suggested that they obtain nourishment by absorption of nitrogenised aliment from the sea-water. The similarity, however, of their pseudopods with those of prey-catching *Reticularia* supports, by analogy, the idea that they take organic particles as food.

In some cases young Foraminifera, resembling what must have been the earliest stages (primordial segments) of the parent, have been found within the shell of an adult individual, and too large to escape by the stolonial aperture. The mother, then, would be at least partially burst for their escape. In other cases such a brood has been seen outside and around the mother, possibly having been emitted in an imperfect state. There seems to be no doubt that the sarcode blasts so often present, and looking like ovules, may be the sources of young broods. It has been remarked by Williamson that some twin monstrosities, as double Foraminifers, beginning in one primordial chamber, may indicate that "fission" is one method of reproduction with these creatures under some circumstances.

XLIX.—Many animalcules formerly classed among the *Infusoria* (which are an important group of the *Protozoa*), especially *Monas* and its allies, have of late years been recognised as belonging to a different protozoan group, more nearly allied to the Rhizopods, inasmuch as at some period of their existence they are in an Amœboid condition, if not living as actual *Amœbæ*. Their typical form is a nucleated corpuscle, with a vacuole, and an external thread-like appendage, or tail-like lash. Hence they have been grouped as the *Flagellata*.*

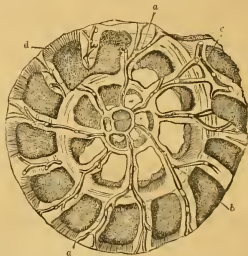


Fig. 34.—SECTION OF THE SHELL OF *ROTALIA SCHREUTERIANA*, NEAR AND PARALLEL TO ITS BASE. (After Williamson and Carpenter.)

Showing—*a*, *a*, the radiating interserial canals; *b*, their internal bifurcations; *c*, a transverse branch; *d*, the tubuliferous wall of the chambers.

* Latin, *flagellum*, a little whip.

Such as these are associated together in groups, like colonies, on various plans; and the constituent members of the compound mass undergo changes leading to the production of new Amœboid and other forms. Such minute flagellate organisms, together with simple protoplasm, make up for the most part the living slime of Sponges.

There are also some small organisms, similar at one time of their developmental growth to little puff-balls and other fungi, and parasitic on plants and wood, which break up and allow innumerable spores to escape; and each of these gives rise to a flagellate Monad, with nucleus and contractile vesicle, and endowed with power of enclosing and feeding on organic atoms. These Monads, becoming Amœbas, join together, and form a large jelly-like mass ("plasmodium"), in which ultimately the fungoid organisms and their spores are developed in their turn. This general or common slime colony, in the meantime, pushes out pseudopods, moves on and on, engulfing food-particles, and, when extended to the utmost, becomes a coarse network, showing the usual circulation (*pseudo-cyclosis*, Wallich) of granules in the sarcode. These are the *Mycetozoa* alluded to above.* The *Labyrinthulea* is such a marine Protozoan. It forms groups of numerous yellowish nucleated corpuscles, usually spindle-shaped, but changeable, very loosely associated together in a net-like tissue, and gliding about within its substance. Some free Amœboids are given off at times by the tissue; but the tapering corpuscles by-and-by mass themselves in groups; these become encysted, and at last each corpuscle, or gelatinous cell, produces four young cells, or spores.

L.—The *Magosphera*, a small spherical body rolling through the water (salt and fresh), consists of numerous vase-shaped nucleated corpuscles fitted together side by side, radiating from the centre, with six-sided outlines, the tapering ends inwards, whilst their outer ends have vibrating fringes, giving a hairy surface to the living ball. Its component cells break up and produce isolated swimming atoms, and these become creeping Amœboids. Each of these, in an encysted condition, divides again and again, until a new compound Magosphere is formed, which breaks the wall and escapes.

LI.—Another life-history of one of the Protozoa, although not that of one of the Rhizopods, is very interesting, and shows us how close is the relationship, and how narrow are the boundaries, between the Protista and the Protozoa proper, and between their several groups. The minute parasites found in the insides of worms and insects, and known as *Gregarina*, have been closely studied. In its advanced stage of growth a *Gregarina* consists of one, two, or three cell-like, nucleated corpuscles of contractile protoplasm, enclosed in a soft, smooth, elastic skin, sometimes furnished with hooks at one end. The "nucleus" is large, mostly round and clear, with a "nucleolus." By contractions of the sarcode just beneath the skin, the *Gregarina* moves creepingly along on the moist surfaces from which it absorbs its nutriment. Reproduction takes place either by division or by zoospores. The latter are produced after a "resting stage," when either a single individual, or several together, have become "encysted;" and, the nuclei disappearing, the sarcode has broken up into a great number of germinative cells, or spores, called Pseudo-navicule. From each of these an Amœboid or *Moneron* escapes, which becomes nucleated, and is transformed into an *Amœba*; and this, furnished with an envelope, lives as a *Gregarina*.

LII.—Like other very minute animalcules, mouthless, but otherwise resembling Infusoria to some extent, the exceedingly small moving bodies seen (with high microscopic power) in decomposing organic infusions of organic substances, and known as *Bacteria* and *Vibriones*, are grouped among the *Monera*. They look like delicate tremulous filaments, and may be straight, curved, or spiral, oscillating, vibrating, or undulating, and are often jointed, or partially divided in the process of being multiplied by "fission."

LIII.—One interesting fact is observable in the comparison of the life-history of Rhizopods with that of higher animals—even with the highest of the Vertebrata. The organic material which is their only living substance, excepting some occasional mechanical support derived from mineral matter, is really a most essential, if not, indeed, in some respects the most essential, substance in even our own bodily system. As the sensitive copper wire in the electric cable is the essential portion of that wonderful cord, so the delicate innermost protoplasmic core of our complex nerve-chord and nerve-threads is essential to the perfection of our nerve-system. In some of the lower animals,

* See also W. S. Kent, "Pop. Sci. Rev.," n.s., No. 18, 1881, p. 97, &c.

as Echinoderms, the nerves are nothing but protoplasmic threads. Impossible as it would be for highly organised animals to move and get their living without bones and muscles, yet without protoplasm, coating their stomachs and other organs, and floating in their blood, to carry on the work of preparing and distributing organic products to the well-being of the whole, they could not exist; and in the nerves protoplasm is the mysterious communicator of both functional activity and the over-ruling will.

LIV.—The Bibliography of the Rhizopoda is immense. Dr. Leidy (in his book often quoted) gives twenty-three quarto pages full of memoirs on the fresh-water forms; but many of these refer also to marine Rhizopods of various kinds. For English readers, W. Archer, H. J. Carter, J. Leidy, and last, but not least, G. C. Wallich, have treated of Amœbians, Actinophrys, &c.; and among foreigners, Auerbach, Cienkowski, Claparède and Lachman, Dujardin, Ehrenberg, Greeff, Hertwig, Lesser, Perty, and Schulze. For Radiolaria, Ehrenberg, Haeckel, Wallich, and others should be studied. For Foraminifera, English students will find, among many others, Williamson, Carpenter, Carter, Parker, Jones, Siddall, and H. B. Brady; and among very many foreign naturalists Ehrenberg, Lamarck, d'Orbigny, von Reuss, Bornemann, Seguenza, Kärner, d'Archiac, and especially Max Schultze.

CLASSIFICATION OF THE RHIZOPODA. (*After Wallich.*)

RHIZOPODA.

1. Nucleus and Contractile Vesicle. PROTEINA.		2. Nucleus; no Contractile Vesicle. PROTODERMATA. Skeleton Silicious.		3. No Nucleus; no Contractile Vesicle. HERPNEMATA.	
Pseudopodia monomorphous (usually of one kind).	Pseudopodia polymorphous. <i>Amœba</i> , <i>Diffugia</i> , <i>Arcella</i> , &c.	Tubular. DICTYCHIDÆ.	Solid. PLAGIACANTHIDÆ. ACANTHOMETRINA. THALASSICOLLINA.	Skeleton Silicious. POLYCISTINA.	Shell not Silicious (Chitinous or Calcareous). FORAMINIFERA.

T. RUPERT JONES.

TYPE PROTOZOA.—CLASS INFUSORIA (INFUSORY ANIMALCULES).

Microscopic Animals—One Cause of the Phosphorescence of the Sea and of the Discoloration of Water—The Life in Infusions—Characters of the Infusoria—Example of Ciliate Infusorians—The Slipper Animalcules—Their Construction—The Flagellate Order—Features—*Cercomonas*—The Cilio-flagellate Infusorians—Characters—The Animalcules of the Ponds in Phoenix Park, Dublin—*Melodinium*—*Ceratium*—The Order Tentaculifera—Characters—*Acinetus*—Classification—The Ectoplasm—The Endoplasm—Origin of the Cilia, Flagella, and Tentacles—How Infusorians Feed—Action and Function of the Contractile Vesicle—The Nucleus or Endoplast—The Colours of Infusoria—The Coloration of Waters—Trichocysts—Reproduction by Fission, Gemmation, and otherwise—Distribution—TENTACULIFERA—SUCTORIA—ACTINARIA—CILIATA—HOLOTRICHA—Paramecium—Prorodontidae—Trachelocercidae—Ichthyophthiriidae—Colepidae—Ophryoglenidae—Pleuronemidae—Lembidae—Family Discovered by Leidy—Opalinidae—HETEROTRICHA—The Largest Infusoria—*Spirostomum ambiguum*—*Condlostoma patens*—*Stentor polymorphus*—PERITRICHA—*Halteria grandinella*—*Urocentrum turbo*—The "Bell" Animalcules—Genera with Vorticella-like Animalcules—HYPOTRICHA—CILIO-FLAGELLATA—FLAGELLATA—*Noctiluca miliaris*.

If a glass tumbler be dipped into a pond or ditch, so as to collect some of the vegetation which is found at the surface and at the sides, besides some clear water, it will invariably be found to contain numerous living things, some of which are just visible to the naked eye, whilst others require a lens or a compound microscope for their detection and examination.

The larger living things are mostly in rapid movement about the water, whilst some cling to the small plants and weed. They are usually small Crustacea, and also the larvæ and active nymphs of insects. Sometimes a water-spider is included in the capture, and frequently small worms are to be seen. Often just visible, and moving here and there, are numerous animals which evidently produce considerable currents in the water, and a lens enables the observer to distinguish that they belong to species of Rotifera of the Vermes.

But the most numerous of the dwellers in the water are either, in a few instances, just visible to the unassisted eye, or are to be seen in countless numbers with the aid of high magnifying powers under the compound microscope. *Amœba* and *Gromia*, minute Rhizopoda, may be found on the weed or on the glass which contains the water, and little moving things are visible which the botanists state are of the nature of vegetables, such, for instance, as the globe-like *Volvox*. But besides Crustacea, Insecta, Vermes, and Rhizopoda, and vegetable organisms, there are thousands of microscopic, or nearly microscopic, animals, which are called Animalculæ, or little animals, and also Infusoria, or animals which live in infusions. Suppose that some sea-water is collected, with a piece of seaweed in it; after a few days a host of those minute microscopic animals will be found in the slime around the weed.

On a warm summer evening, as darkness closes in, the ripples of the sea become luminous, and flashes of light start from one part of the harbour or coast-line, and stretch far and wide, expanding in ever-widening circles. This particular form of phosphorescence of the sea is due to the presence of myriads of minute animals, which do not belong to any of the groups of animals hitherto described in this work, and which must be ranged amongst the Infusoria. Again, discoloration of fresh and salt water often occurs, and it is found to be produced by crowds of microscopic creatures. In water which is brackish, in water which contains a considerable quantity of salt, in water which may be icy cold or very warm, and in water which is impregnated with fetid gas and decaying animal and vegetable remains, these simple, active, wandering, or sedentary microscopic creatures, which constitute the lowest forms in the animal kingdom, and which in some instances are separable only in a very arbitrary manner from the simplest and lowest members of the vegetable kingdom of nature, may be found in abundance. Place some of the pond water, deprived of its visibly living and moving things, under a microscope with a low power, or such an one as will magnify about forty times: minute bodies, hitherto invisible, are seen moving rapidly across the field of vision (Fig. 1), sometimes rushing across, so that only an indefinite idea can be gleaned of their shape; or



Fig. 1.—INFUSORIA IN THE FIELD OF THE MICROSCOPE.

going along more slowly, either steadily or turning over from side to side, and screwing themselves, as it were, forwards. Sometimes a dozen or more will come within the range of vision, and twist and turn in every direction, and suddenly rush off, moving so as not to come in collision. Occasionally a globular-shaped thing will come by and stop, and just as suddenly will leap, as it were, in the water, and go right out of sight. Now and then a great current of water appears to be in motion, near the side of the field of vision, and if the slide holding the water be moved, so as to bring it beneath the eye, some balls, like specks, are seen united to delicate stems. They produce much movement in the water, and are suddenly dragged backwards towards their fixed point. Here and there, settled down and resting on a kind of stem, some pear-shaped things may be seen, with delicate hairs sticking out from their ends. A still higher power of the microscope, which will magnify from 300 to 1,000 times, enables other and smaller creatures to be seen, and renders the minute structures, of the larger, visible and capable of study. Amongst the smaller ones are little bag-shaped things, with one or two hair-like projections—the cilia

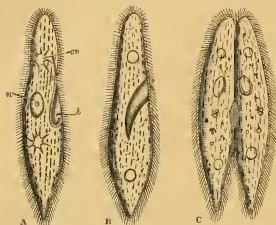


Fig. 2.—*PARAMECIUM AURELIA*.

A, Lateral, a, ventral surface; c, in conjugation; cn, contractile vesicle; n, nucleus; b, oral aperture.

which keep them in movement—and in places here and there are multitudes of little moving things, mere lines of matter, with an end produced into a hair-like tail or flagellum. These are amongst the simplest of living things, and may be animal or may belong to the lowest plants. The microscope reveals, amongst the larger kinds, that they move in consequence of the vibration, or to-and-fro movement of microscopic cilia, and that the kinds which are stalked can be retracted by the contraction of a granular tissue resembling the simplest form of muscle.

If lately-collected rain-water is examined in the hope of discovering any of these minute forms of life, disappointment will occur. But if some hay, or any vegetable matter, be allowed to soak in pure water exposed to the air, or if pieces of flesh, brain, blood, or any animal substance, be placed in water, and also exposed for a

day or two, a great many species of these animalcules, or Infusoria, the individuals being in vast multitudes, will be distinguishable. Certain kinds of these animalcules are almost invariably to be found in water in which particular vegetable or animal substances have been soaked, and a succession of kinds is often observed to occur as the infusion gets old. The free access of air is requisite for all this, and the hay and animal substances form the food of the minute creatures, whose derivation is not from the minute structures or broken-down tissues of the plant or animal. The air contains the extremely minute spores, or reproductive particles, whence the animalcules spring. There is no spontaneous generation of these animalcules, and no turning of dead animal or vegetable tissue into them. The term Infusoria, or animals of infusion, merely relates to where they are to be found in most instances, but not invariably, and it must be carefully noted that the animalcules are not derived from the infusions. Certain infusions suit particular kinds of Infusoria, and these particular species are to be found in them.

The Infusoria are exceedingly simple in their construction, may be said to be uni-cellular, and are allied, as Protozoa, to the Rhizopoda. There is this distinction, however, that whilst the majority of the Infusoria move actively, and a great number are sedentary, or move during some part of their life-cycle, they rarely have silicious or calcareous tests,* and the pseudopodia, which sometimes exist, never run together as they do in Gromia and Amœba amongst the Rhizopoda. The body is usually soft, and there are one or more contractile vesicles. A nucleus exists, and there are vacuoles which contain food. The outside of the body is ciliated in a great number, has but one or two long cilia in front in others, and one group has no cilia, but tubular processes project from the more or less pear-shaped body, and really act as suckers.

The following are examples of the four great divisions or orders of the Infusoria.

* Haeckel has described some with tests.

Pond water and artificial infusions of hay yield, as a rule, considerable numbers of a rather large animalcule, which may be from $\frac{1}{96}$ th to $\frac{1}{120}$ th of an inch in length. They are free swimmers and long-bodied, being narrowish and bluntly pointed at one end, and more sharply at the other. They are flat also, and there is a groove in the body extending from the left side of the front part of the body backward and underneath to about the middle. They are about four times as long as broad, and their shape has given them the name of Slipper animalcules (Fig. 2).^{*} They are not quite symmetrical fore-and-aft, and the back and ventral surface can be distinguished. The whole of the body is covered with a fine down of cilia of nearly or quite equal size throughout, which vibrate with considerable rapidity, enabling the animal to move here and there rapidly, to turn round on its axis, to swim backwards and forwards, and even to turn like a screw on its long axis, throwing the under part up and over, to replace the back in its original position. As these animalcules, which have a yellowish-brown tint by transmitted light, move vigorously along, they rush over the field of the microscope and re-enter, and should there be a collection of vegetable mucus, numbers will come together and push in and amongst it, passing here and there, but never brushing up against one another, so as to come into collision. It is evident that they have some power of slightly altering the shape of the body, and that the slit on the underside has to do with the inception of food. The cilia, when the animal is moving or comparatively still, form currents in the water, and those in the neighbourhood of the slit produce whirlpools, down which rush minute particles of food. These pass down the slit, and enter the body at a kind of mouth, and they there come in contact with the soft inner substance composing the animalcule, and sink into it, being surrounded by a drop of water. Several of these morsels of food are to be seen lying in clear spaces filled with water or food vacuoles, and as the whole of the soft internal structure tends to move in an amoeboid kind of manner, the vacuoles change their places. This gave rise to the false idea that the Infusoria were many-stomached, or "polygastrica." In this internal substance, or endoplasm, some other things are to be seen. Firstly, there is an oval body with a small dark spot in it, the nucleus or endoplast, and the nucleolus or endoplastule; secondly, there are two spots, one close to either end of the body, which gradually become more visible and transparent, and suddenly shut up and disappear. They are the contractile vesicles, and it is commonly observed that, if the animalcule is subjected to any pressure, these light spots present rays passing from them into the endoplasm, so as to assume a stellate appearance. The opening and closing of these vesicles are very regular. There is a most delicate tissue covering the whole animalcule, and another from which the cilia spring. They are elastic, and appear to be endoplasm in a less watery condition. They form the ectoplasm. Between these layers and the minutely-granular endoplasm is one of exceedingly delicate rod-like bodies arranged point outwards, and they are called trichocysts.

The animalcule evidently respire through its outer ciliated coat, takes in food through the mouth at the bottom of the slit, has several food vacuoles, which finally come near the surface skin, and discharge the undigested matters. As the food, consisting of minute spores and animal and vegetable matters, is digested, the protoplasm of the body is added to, and the circulation and removal of effete matters are in relation to the contractile vesicles.

The creatures languish if the water remains too long without exposure to air, but otherwise their movement appears to be constant. Occasionally two will approach and cling together by their oral or ventral surfaces, and it is occasionally noticed that a large individual contracts midway and finally separates into two. If watch be kept long enough, the animalcules will be noticed to become quiet, to take on a globular form, and to have the ectoplasm dense and non-ciliated. Sooner or later the globe will burst, and a host of minute moving things will come forth, each of which is a young animalcule.



Fig. 3.—CERCOMONAS TYPICA. (Saville Kent.)
A, Adult; B–I, different stages in the development. (After Döllinger and Drysdale.)

^{*} *Paramecium aurelia*.

This is a common instance of the order of the class Infusoria, called, from the body being more or less covered with cilia, the INFUSORIA CILIATA.

The highest powers of the microscope, and glasses possessing very perfect defining qualities, are requisite in order that the next type of Infusoria may be seen perfectly. The little creatures are free swimming, and the body is long, egg-shaped more or less, but it has a projection so as to render it more or less spindle-shaped or fusiform. In front, there is a single filament prolonged from the body like a very large cilium, and a longer one, about twice the length of the body, projects behind. These are the flagella. There is a single minute contractile vessel in the body on one side, and the nucleus or endoplast is spherical, and near the centre of the animal. There is no mouth or special aperture for food, and there are no cilia on the soft external part, which barely differs from the inner mass of the minute body or endoplasm. Only measuring from $\frac{1}{2000}$ th to $\frac{1}{3600}$ th of an inch in length, these minute Infusoria are found in vegetable infusions. They swim freely by means of their long flagella, and also crawl over substances very much after the fashion of Amœbæ. It may happen that one may be seen larger or broader than the others, and, after a while, the observer is repaid by seeing the body

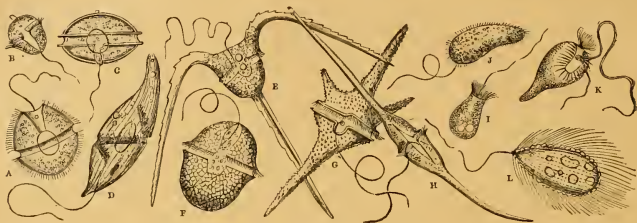


Fig. 4.—GENERA OF CILIO-FLAGELLATE INFUSORIA.

A, *Melodinium uberrimum*; B, *Glenodinium acuminatum*; C, *Diplopsalis lenticula*; D, *Gymnodinium spirale*; E, *Ceratium tripos*; F, *Peridinium tabulatum*; G, *Ceratium longicorne*; H, *C. fusus*; I, *Stephanomonas lecellus*; J, *Mitophora dubia*; K, *Heteromastix protiformis*; L, *Mallomonas piasilli*.

split down its length, and two creatures swim off, each supplied with a front and rear flagellum. If two come in contact, they join together, like Amœba, and after a while the mass loses its flagella, and a vast number of spores are formed out of the endoplasm. These escape, and gradually form into creatures like those which produced them.

Exceedingly minute particles of food are taken in by the surface of the body at no particular spot, and the undigested matters simply pass through the endoplasm to the outside. This Infusorian is a *Cercomonas** (Fig. 3), and is a fair example of the order called the FLAGELLATA. Members of this order are distinguishable—in some instances with difficulty—from moving spores of the lower plants, and indeed it is in this group that the junction of the animal and vegetable kingdoms is to be found. The Flagellata contain very simply-constituted organisms, and some which are less so, and of these last the phosphorescent marine Noctiluca is an example.

Another type of Infusoria combines, as it were, the characters of the ciliated animalcules and those which have a flagellum. The kinds which are associated with it are mostly found in sea water, and in many parts of the globe. A few, however, are to be noticed in fresh water in the United Kingdom. Thus, Professor Allman found enormous multitudes of an Infusorian about $\frac{1}{5000}$ th to $\frac{1}{10000}$ th of an inch long, of a reddish-brown colour, in the ponds in Phoenix Park, Dublin. It had an almost globular body, with a constriction or furrow running round the middle, and a groove passing from this furrow over the body to the top. The whole surface was covered with extremely delicate moving cilia, and a long, slender, active cilium or flagellum was found to be placed on the top in the groove. A large endoplast (nucleus) was in the centre of the animal, and just below the origin of the flagellum was a small, intensely red spot. A contractile vesicle occurs in this type. The brown colour of the ponds in

* *Cercomonas typica*.

1854 was owing to the presence of prodigious numbers of this species of *Melodinium** (Fig. 4, A). The tint was sometimes uniformly diffused through the water, and at others was collected in dense clouds, varying from a few to upwards of 100 square yards in extent. Later on, the coloration of the ponds, brought about by the agency of these minute organisms, had much increased in density. By the 9th of July the water was so dark and brown, that a white disc, half an inch in diameter, was invisible when plunged to a depth of from three to six inches; while a copious exit stream, constantly flowing away from the ponds, presented a similar deep brown hue. In many places the animalcules had descended from the surface, and were found congregated in immense masses near the bottom of the water. In these instances they had, for the most part, become quiet; the flagellum and cilia had disappeared, and a kind of transparent tissue had been developed around each one. During the life of these curious animalcules the body divides across, and two individuals are formed; and this proceeds time after time, adding rapidly to the numbers of individuals. Moreover, the encysted state is accompanied by a breaking-up of the internal protoplasm or endoplasm into numberless particles, each of which will grow into a form resembling the parent.

In examining the phosphorescence of the sea, moderately large animalcules of $\frac{1}{60}$ th of an inch long are occasionally seen. They are light-emitting, of a yellow colour, and have a remarkable shape and construction. An external coat, transparent but hard, exists, and it covers the soft structures. It is prolonged into a long horn in front and behind, and the body is nearly globular, with a depression around it, and a groove crossing this at right angles. The appearance is very peculiar. Cilia around the depression, and a very long and delicate flagellum, which moves like the lash of a whip, starts from the groove. The long fore-and-aft projections are quite stiff, and the only mobile parts are the cilia and flagellum. This Infusorian belongs to the same order as the last, and to the genus *Ceratium* (Fig. 4, B). They are *CILIO-FLAGELLATA*.

A very different kind of animalcule must be taken as the example of the next and last order of the Infusoria. If the surface of water-plants in the Birmingham and Stratford Canal, for instance, be observed, a fine Infusorian $\frac{1}{75}$ th to $\frac{1}{160}$ th of an inch in length may be seen fixed on a long stalk which is straight and stiff. The body, placed at the top, is contained in a cup-like sheath, with a triangular outline, widest where free, and where there is a slit which enables the endoplasm to communicate with the water outside. The endoplasm (finely granular) does not fill the cup, but collects in an egg-shaped mass which has a contractile vesicle, and the nucleus or endoplast is in the form of a band. There are neither cilia nor a flagellum, but a bundle of numerous tentacles exists at both ends of the free end of the cup-shaped sheath, and they are processes of the body. The tentacles have a disc-like top, and do not move so as to enable the animal to swim. They are catchers of prey, and any small animalcule coming in contact with them is stopped, and its delicate tissue is penetrated by their sucker-like disc (Fig. 5)†. By-and-by the endoplasm of the victim is sucked out of it, and acts as the food of the catcher. The young of these stationary Infusorians are active, and move well and rapidly with the aid of cilia, and thus resemble the Ciliate Infusoria. These Infusoria constitute the order *TENTACULIFERA*.

There are, then, four great groups or orders of Infusoria typified by the species of the genus *Paramecium*, *Cercomonas*, *Melodinium*, and *Acineta*, and they constitute the orders *Ciliata*, *Flagellata*, *Cilio-flagellata*, and *Tentaculifera*.

A host of species, included in numerous genera, is classified under each of these orders, and there is the greatest diversity of shape and of method of life amongst them; but the main features and especial characters of the orders are so definite, that there is no difficulty in classifying any Infusorian, which has attained adult age, in its proper group.

From their great vivacity of movement, their many varieties of cilia, the invariable existence of contractile vesicles, and endoplasts, and sometimes trichocysts, the *Ciliata*, or the Infusoria which move by and are more or less covered with cilia, strike the observer as of predominant zoological importance. They are clearly more highly organised than the Infusoria which have only flagella. And these last appear to be lower in the animal scale than the creatures which have a few cilia,



Fig. 5.—*ACINETA TUBEROSA*, WITH TENTACLES EXTENDED AND CONTRACTED.

* *Melon*, a peach; *dine*, a vortex.

† *Ceratium fusus*.

‡ *Acineta tuberosa* (Ehrenberg).

and a flagellum also. The fact that the Tentaculifera are totally unlike the other Infusoria in their adult age is very remarkable; but it is evident that before they attain maturity they resemble the Ciliata. New structures are thus, by evolution, given to the Tentaculifera, and they have considerable affinities with the Rhizopoda. Their adult form is in advance of the ciliate young one, and the order Tentaculifera must stand at the head of the Infusoria. Next come the Ciliata, then the Cilio-flagellata, and, finally, the Flagellata.



Fig. 6.—*DENDROSOMA RADIANUS*. (After Saville Kent.)

a, Embryus escaping with cilia; *b*, buds producing embryos like the parent; *st*, stolon.

The Infusoria are uni-cellular, and this is true where there are two or more individuals in close contact, or where a common stem supports the bodies of others, which may be numerous. For in these instances subdivision of the parent has produced the independent creatures. In the Tentaculifera, however, the most highly-organised amongst the Infusoria, in the species called *Dendrosoma radians* (Fig. 6), there is a root common to many trunks which give origin to branchlets terminating in a bundle of tentacles with suckers. This arrangement can hardly be called uni-cellular; there is, however, no actual cell division, and indeed the ordinary idea of the single cell is hardly applicable to this and many other Infusoria.

The simplest Infusoria belonging to the Flagellata, which have no special spot for the ingestion of food,* have no distinct environing membrane over their soft finely granular protoplasm, and they can assume various shapes for a while. Others belonging to the same group have the outside of the

body slightly more solid than the rest. In the Ciliata the presence of an outer membrane is evident, and it is possible to distinguish, on some of them, four layers around the soft semi-fluid central endoplasm. On the outside is a perfectly transparent structureless membrane, and it is a true cuticle. It forms a sheath for the stalk of some Infusorians, and the covers or shields (*lorica*) of others (Fig. 7). It is composed of formed material, and is independent of the nutrition of the animal. Under the hyaline outer layer there is, without exception amongst the Ciliata, a firm homogeneous elastic and contractile layer, of which the cilia and their various modifications are the offshoots. They penetrate the outer layer and arise from this inner one. In some, but not all, of the Ciliata, there is a layer beneath this last one, which is more or less fibrillar, and highly contractile. It is the muscular, or myoephan layer of Haeckel. In the genus *Stentor* (p. 367) it is highly developed, and it can be seen, by using high and well-defining powers, in the common *Vorticella*, in which it forms the central, or contractile, part of the stalk, and a thin layer continuous with this is in the body. The fourth layer is not invariably found, but it has been already noticed in the description of a *Paramecium*. It produces and holds in place the minute rod-like bodies called trichocysts, which will be noticed farther on. These layers constitute the ectoplasm.



Fig. 7.—*TINTINNUS LAGENULA*, SHOWING THE LORICA AND THE CROWN OF CILIA.

The endoplasm, situated within the ectoplasmic or outer layers, is more or less fluid, granular, and coloured glairy protoplasm. It is tolerably immobile in many Infusoria. In most it is subject to amoeboid movements, to a faintly-developed rotatory movement, and to what may be called streaming. In some instances the movement is strong, and resembles that of the cyclosis of plants, as in *Vallisneria* and *Chara*. Noctiluca, the phosphorescent flagellate Infusorian, has the endoplasm more or less in the form of a network, with vacuole spaces, and a quantity of granular substance, and this condition is seen in other forms.

* Group *Pantostomata*.

The spaces occasionally seen in the endoplasm, and which transmit light more readily than the rest, are called vacuoles; they may exist as spaces filled with water, and usually they contain, besides the water, a greater or less portion of the vegetable or animal matter which has been introduced into the body as food. They must not be confounded with the contractile vesicle. Besides these, there is the nucleus or endoplast, which is surrounded, in part, by the granular semi-fluid endoplasm, and which is also in contact with the deeper layers of the ectoplasm. Colouring matter, diffused or localised, is seen in the endoplasm, and this inner protoplasm produces the minute particles or spores which escape and develop into new individuals.

In all Infusoria, the cilia and their varieties, the flagella and the tentacles, are extensions of the substance of the body. In the minute flagellate animalcules the flagellum, which is an elongated whip-like cilium, is an extension of the delicate ectoderm: in the Ciliata the cilia arise from the special layer beneath the hyaline cuticle; and the long suckers of the Tentaculate order are probably extensions of the same tissue. The cilia differing in dimensions and shape in some Infusoria are the minute hair or eyelash-looking vibratile appendages which mainly move their possessors, or produce currents in the water when the Infusorian is fixed. They appear to move actively in one direction, and to return to their original position by their elasticity.

The tops move forwards and backwards, and it is noticed in certain species that the ciliary lashing is consecutive in a series, and that it produces the appearance of rotation, as in the Rotifera (pp. 245-9). They are semi-solid and elastic, and they are moved by the contraction of the endoplasm at their base. The vibratile cilia are arranged in bands only, in certain families, and universally in others. Some Infusoria have some cilia which are elongate, flexible, but not movable, and they are then called setæ; and in one interesting genus (*Halteria*) these long hairs are utilised when the animal makes its sudden jumps. Some Ciliate Infusoria have these setæ stout, and placed on the ventral, or under-surface of the body, or at the extreme ends, and then they are called styles. In some instances the ends of the styles are branched or feathered. In a family of the Ciliata, the Oxytrichidae (p. 371), there are claw or sickle-shaped appendages, which are modified setæ, called hooks, or uncini, and some of the species carry all these remarkable outer structures for the purposes of locomotion and prehension (Fig. 8). The body is, in some Infusoria, furnished with fin-like, thin, vibratile membranous fringes (Fig. 9), and in one important group of the Flagellata the collar of the animalcule, which exactly resembles that of the cell of the sponge, has its protoplasm in streaming movement, which carries the particles coming in contact with the outside over the top to the mouth within. The tentacles of the Tentaculifera resemble the pseudopodia of Rhizopods more or less; some have a disc-shaped sucker at the top, and are hollow, being filled with semi-fluid endoplasm. A spiral fibre is seen on the outside of some tentacles, and in one family there are no terminal suckers.

Whilst some Infusoria take in food at any part of their body, the morsel simply sinking into the soft protoplasm, and carrying with it a small quantity of water, forming thus a vacuole, in others it is carried in the direction of a particular orifice, slit, or tubular cavity, by currents in the water produced by certain cilia. In some species the mouth-opening is always visible, in others it is small, and only visible at the time of the capture of prey, and in a few it is so large that a morsel is often swallowed nearly as large as the captor. The mouth, in the most perfect forms, consists of a passage in the ectoplasm structures, which can dilate, and the lining of which is plaited, folded, and even furnished with a layer of rod-like teeth (Fig. 10). This part is often capable of protrusion, and on opening it leads to the exposed semi-fluid endoplasm, and not to anything like an œsophagus and stomach. The morsel simply sinks into the mass with a little water, and forms a vacuole.

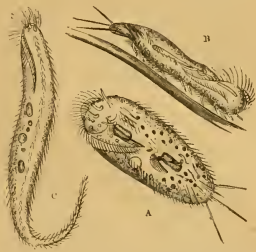


Fig. 8.—A, B, *SYLONCHIA MYTILUS*, SHOWING CILIA, STYLES, AND UNCINI; C, *EUROLEPTUS*. (After Stein.)



Fig. 9.—*LEMBUS VELIFER*.

One or more food vacuoles may exist, and as one is formed subsequently to the other, the oldest vacuole is the most deeply embedded, and if the animalcule be fed with carmine, a number will be noticed forming a series in the endoplasm, and moving with it. Much of the food thus received is digested, and the rest is evacuated in a definite direction, and sometimes through a special opening in the ectoplasm—the anus. In many species, however, the faecal matters pass out at any point.

When one of the Infusoria is lively and feeding, and is being examined under high powers of the microscope, one or more spots, with a circular or radiating outline, will suddenly appear near the ends of the body. Each begins in a point of greater transparency than the body structure all around it, increases rapidly in diameter, and often assumes a tinge of colour, retaining, however, its transparency. It is a light-transmitting space, with the slightly denser structure of the inside of the animal around it. As the light from the reflecting mirror of the microscope traverses the tissue of the Infusorian at this now enlarged spot, it seems to be unsteady, and this depends upon water passing into this really globular space, which, seen under the microscope, presents the appearance of a circular area (Fig. 11, A, *cv*). It is evident that water flows into this space, which is situated really in the layer immediately over the soft endoplasm; there is no envolving membrane to it. Suddenly the circle of light



Fig. 10.—A, PHORODON MARGINITIFER; B, PHARYNGEAL ROD-FASCICLE OF; P. NIVEUS C, DITTO OF NASSULA.

cv, contractile vesicle; *n*, nucleus.

closes in on its centre, and the appearance of a light point amongst the darker surrounding matter suddenly ceases. The tissue closes in on the space, moving in on all sides, and this is done not passively but actively, for in some instances a tremor can be seen to occur over the whole animalcule at the time of the contraction of the space. Moreover, although the space enlarges slowly, it contracts very rapidly, as a rule. If the Infusorian be kept for some time under observation, the absence of food and fresh water will begin to diminish its energies, and it will especially influence the rapidity of the dilatation and subsequent contractions of this space, which is termed a contractile vesicle. The appearance of the light spot is not so frequent; it commences languidly, and enlarges slowly, and finally contracts, or disappears less abruptly than in the instance of the vigorous animal. After a while, the appearance and disappearance of the spot—or, in other words, the dilatation and contraction of the contractile vesicle—become slower and irregular, and they cease with the death of the animal.

More than one contractile vesicle may exist in the same species, and their position in the body, although generally well defined, is not invariably in the same spot. Usually, the vesicles are nearer the ends of the body than the central part, and when they are fully dilated they occupy not only a portion of the body hitherto filled with endoplasm, but come close under the outer and denser tissue. In the instances where the contractile vesicle presents the appearance, under the microscope, of a circular space,

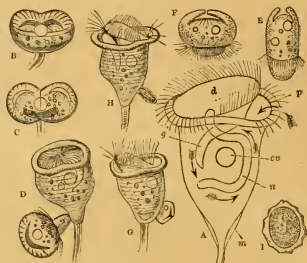


Fig. 11.—A, DIAGRAM OF VORTICELLA NEBULIFERA; B-D, PHASES OF LONGITUDINAL FISSION; E-F, PHASES OF ATTACHMENT, AND G-H, OF INCORPORATION OF FREE EMBRYO OF *V. MARINA* (After Greeff); I, ENCYSTED STAGE OF *V. MICROSTOMA*.

d, disc; *p*, peristome; *g*, gullet; *cv*, contractile vesicle; *n*, nucleus; *m*, muscular coat. The arrows denote the course of circulation of food particles.

of observations, to extend from it into the endoplasm during the active contraction or dilatation. The water contained in the vesicle must go somewhere, and must be derived either from within the body or from without, or perhaps from both directions. Occasionally, however, a very indistinct movement can be seen radiating, as it were, amongst the granular, or almost homogeneous protoplasm of the animal, subsequent to an active contraction of the space. No visible movement accompanies the infilling. There are many Infusoria, such as the species of *Paramecium*, in which the contractile vesicle, when fully expanded, is not limited

by a definite circle of endoplasm, but has rays, or tubular passages, tapering outwards around it (Fig. 2, *cr*). The passages are numerous, and may be seen to ramify at their extreme ends, and they are weak spots in the cortical layer over the more fluid endoplasm, extending far and wide from the vesicle. These passages transmit light more readily than the protoplasm in which they are placed, and it therefore occurs that, as water fills them, and they increase in diameter and length, they are nearly as light-transmitting as the main space with which they are continuous. They become largest just before the contraction of the vesicle, and they sometimes do not disappear until after its contraction. It is evident that the watery contents of the passages are pressed upon by the contraction of the surrounding protoplasm, and that this water and that of the space penetrate, during contraction, into this environing substance. Movement may be noticed under the outer tissue, here and there, within and along the lines of the passages. More or less defined communications exist between the outside water and the contractile vesicles through the ectoplasm, and the vesicle receives pure water from without, and collects and expels the impure water from within the animal. It is evident that the function of the contractile vesicle is of great importance to the animal, and it may relate to the elimination or removal of certain soluble matters resembling the urinary secretions. It may also relate to an internal circulation of water.

The rhythm of the dilatation and contraction is very remarkable, and Saville Kent states that "the time occupied between the consecutive pulsations of this organ is found, under normal conditions, to present a constant average among individuals of the same species, varying from a few seconds only in certain forms, to over sixty or even one hundred seconds in other types."

The nucleus or endoplast with its contents resembles, in some Infusoria, that of the simplest vegetable cell. In its simplest form, noticed in some of the Flagellata, the endoplast is more or less spheroidal, and may or may not contain a nucleolus or endoplastule. Saville Kent has given an admirable *résumé* of the knowledge which has been accumulating regarding these structures, and he notices that the first step towards complexity is in the genus *Euglena* and its allies, in which the endoplast becomes ovate in outline. A sausage shape is assumed in some Ciliata, and its ribbon shape in *Vorticella* has long been known.

In some of the Tentaculifera the nucleus is branched, and in some Ciliata, such as *Condylostoma patens* (Fig. 12), it presents a necklace appearance, and in others the swellings are widely separated by narrow processes. More than one endoplast exists in the Oxytrichidae, one being in front and the other behind the centre of the body; and in some species of Opalina the endoplasts are numerous. In its more complex forms the endoplast is enclosed within a very delicate transparent membrane. The nucleolus or endoplastule is sunken within the substance of the endoplast in some forms; it is attached to the inside of the membrane of the endoplast in others, and on the outside in a few Infusoria.

Two or three endoplastules exist in some, and in *Vorticella* they are granular fragments, one or more of which become enclosed within each of the segmental portions into which the endoplast becomes separated, during the process of internal budding, which will be noticed farther on. The endoplast is in contact with the softer internal substance of the Infusoria (the endoplasm), and also with the inner part of the cortical structures or ectoplasm.

The Infusoria are usually more or less coloured, and the Flagellata, with rare exceptions, have a small brilliant crimson spot at one end of the body; in one genus there are two of the spots. Amongst the Ciliata the red spot is rarely seen, and one genus has a black one; but the Tentaculifera do not have these pigment spots. Formerly they were considered to have to do with vision, but this is an error, and the common term "eye spot," is therefore incorrect. Diffused colouring matter tints

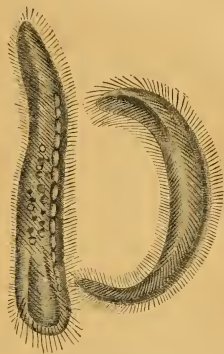


FIG. 12.—CONDYLOSTOMA PATENS, SHOWING MONILIFORM ENDOPLAST.

most Infusoria, and the smallest animalcules or monads belonging to the Flagellata have a pale glaucous or fluorescent hue, and Saville Kent notices that this is visible under high magnifying powers. It is probably due to reflected and not to transmitted light. Most of the Flagellata are coloured, and the species of one great group, the Euglenidæ, are of a brilliant green, the colour being diffused in the endoplasm. The colour is identical with that of the lower plants, containing chlorophyll, and it is remarkable that this green tint should turn to red. Thus in *Astasia sanguinea* the green colour, which gives a tint to the water in which the myriads of the animalcules swim, is suddenly turned to red, accounting for old and new traditions regarding the turning of fresh waters into blood. Ray Lankester has shown that in the genus *Stentor* the green matter, like that of *Hydra viridis* and *Spongilla*, is a chlorophyllous substance similar to that of plants. One *Stentor*, however, has a blue colouring matter which is produced by a special chemical combination called Stentorin. Quite as many Infusoria have a diffused pale amber to deep olive colour as green, and most of the Tentaculifera and Cilio-flagellata have these dull colours.

Saville Kent notices that some of the Flagellata differ from the majority by the presence of the olive colouring on two lateral bands on the body. In the Ciliata, a Leucophrys is of a brilliant crimson colour, and a Nassula has numerous violet granules in its endoplasm. Minute crimson granules have also been noticed in the contractile tissue of the stalk of *Vorticella*.

In some Euglenidæ, there are bodies in the green endoplasm which are of a starchy nature. Finally, there are the accessory structures of the cortical part of some of the Infusoria or the trichocysts. As has been already noticed (p. 355), they are visible in *Paramecium aurelia*, in the form of very slender rods crowded together in a layer, their points looking outwards beneath the outer cuticle. Under the action of weak acetic acid, these trichocysts force through the cuticle and beyond the cilia. Ellis, an Englishman, writing more than a century since, discovered these curious bodies; and Allman, in 1855, established their true nature, and assimilated it to a certain extent with that of the nematocysts of the Corals. But there are essential distinctions. Allman found that the minute fusiform rods, under external irritation, become suddenly transformed into long hair-like filaments, which projected from the whole surface. By carefully crushing examples, and isolating the trichocysts in their unaltered condition and in their fusiform shape (that is, swollen in the middle, and narrow at each end), it was found that after a few seconds the shape was altered with a jerk, as if some previous state of tension were relieved. A spheroidal shape was assumed by the hitherto fusiform rod. Then, in a few seconds, a spiral filament was observed to become rapidly evolved from the sphere, apparently through the rupture of a previously confining membrane. The spiral fibre unwound, and became straight and rigid. In their most extended state, these bodies were found to consist of a long rigid spiculum-like half, sharp at one end, and continued at the other into a very filiform part, which is bent more or less. Probably they have a noxious influence on minute living things.

Some Infusoria appear to retain the same shape under all kinds of circumstances; others enlarge laterally or longitudinally, and even twist, as they move here and there or endeavour to get in between substances, but they speedily return to their normal figure. Such irregular changes of shape as are seen in the Amœboids are not often found in the Infusoria, but a very different appearance is presented by some during active motion and feeding and during quiescence.

Nothing is more common than to see many Ciliated Infusoria moving along with the shape of their bodies altered by the presence of a greater or less central constriction, and if one of them is watched, it will be seen

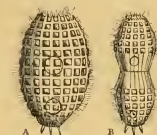


Fig 13.—COLEPS HIRTUS.
(After S. Kent.)

A, Showing ornamentation; B,
transverse fission.

to separate, into a front and a hinder part, and each will become a separate individual (Fig. 13). Division also occurs lengthwise. It has been computed that, in the instance of *Stylonychia mytilus* (p. 371), no less than a million of independent beings were derived from repeated fission of a single individual in the course of ten days. When Infusoria form colonies, they arise from the repeated binary subdivision of the first stock, and in some instances masses result, slime-like, many feet in extent (*Epistylis grandis*, p. 370). In the majority of species, the division is across the body, and in others in a longitudinal direction, especially in the

Vorticellidæ. In the Stentors and some other genera the fission is oblique. The endoplast divides in every instance, and part remains with each individual, and the other organs, such as the mouth, anus, and contractile vesicle, are developed where they are wanting.

Some Infusoria increase by a process resembling budding, and in this process, the important endoplast contributes a little process which accompanies the protrusion of the body membrane to form the bud. In *Noctiluca* (p. 374) the protoplasm beneath the cuticle becomes broken up into nodular fragments, which are protruded upon the external surface, and are finally liberated as very minute bodies resembling monads, and these grow into adult *Noctiluca*.

In some instances the young grow within the body of the parent, but only at the expense of the endoplast. Portions of this separate and become embryos, which escape with their cilia, and either resemble the parent or grow into its shape as in the *Tentaculifera*.

Another method of reproduction is when the Infusoria become quiescent; a delicate covering is then formed over the body, and the quiet and encysted creatures have their internal tissue broken up into myriads of minute particles, which escape, and finally assume the shape and destiny of the parent. It is found that sometimes an intermediate amebiform condition occurs (Fig. 14).

Infusoria also reproduce after a process which somewhat resembles the conjugation in Algae amongst plants. Swimming, or fixed by a common stalk, two animalcules come in contact by their oral surfaces, and remain united for a limited period. They swim about, and exist as one, and in the *Flagellata* the flagella are withdrawn, and amebiform processes are cast forth. In other instances the junction of different individuals, one often larger than the other, persists. Under both circumstances the reproductive energy of the couple is intensified. How, is a matter of debate, but late microscopical researches by Bütschli and Englemann show that during the process the original endoplast in both animalcules breaks up into a number of fragmentary portions, and becomes lost among the endoplasm. By-and-by a new endoplast is constructed through the gradual assemblage and union with each other of fragmentary particles, and the new endoplast is common to both of the animalcules when the conjugation is complete and lasting, as in *Vorticella* (Fig. 11); while two or more, according to the normal number, are reproduced where the conjugation is transient as in *Paramecium* (Fig. 2). Bütschli denies that embryos are subsequently developed from the endoplasts, and he considers that the conjugation is a mere vital stimulant to the decaying energies of the animalcule. Before passing on to a short classification of the Infusoria, it is necessary to mention that they have a most extraordinary distribution. Some families inhabit salt water, others fresh; some species live in running water, others in stagnant pools. Many species are parasitic on, and others within, other Infusoria, and many groups of *Invertebrata* and *Vertebrata*. Many are only found in animal, others in vegetable, infusions. One group is mouthless and essentially endoparasitic. The *Opalinidæ* inhabit the alimentary canals of insects, frogs, toads, and the aquatic *Annelida*. Some *Ciliata* inhabit the stomachs of ruminants, some live in the human gut. Others live fixed to fish, or crawl about the *Hydra*. The *Flagellata* are found in fresh and salt water, and are often parasitic, and some inhabit human urine. In searching for ordinary and well-known forms, the surface of pure and coloured fresh waters, and the leaves of the plants, should be examined, and the waters of bogs and the sea-shore yield many new forms. The artificial production of Infusoria, by infusing hay, meat, &c., depends on the existence of the germs in the air, in the water, and collected about the plants.

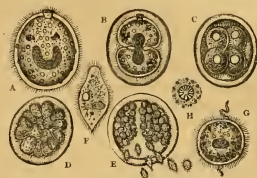


FIG. 14.—*ICHTHYOPHTHIRIUS MULTIFILIIS*.

(After Fouquet.)

A, Adult; B-G, different stages of development (E, escape of young); H, oral apparatus.

ORDER TENTACULIFERA (*Huxley*).

An example of this order has been noticed already, and it explains the characters of the group. They are animalcules inhabiting either salt or fresh water, and many are parasitic on and within other

Invertebrata. They have tentacle-like processes, derived from the cuticle or from the endoplasm, or from both of these parts. The body contains an endoplast and one or more contractile vesicles. They increase by division across or longitudinally, and also by budding, which may be external or internal. Some of the young (embryos), on escaping from the parent, are ciliated, and the cilia may be arranged over the whole body, or in the form of a wreath around the body, or only on the under surface. With growth the state changes, and the cilia are lost. Others resemble the parent. The adults have neither cilia nor flagella. The majority of species are sedentary. The Tentaculifera are divided into two sub-orders, in one (the Suctorior) the tentacles are wholly or partially suctorial in their office, and in the other (the Actinaria) they are not suctorial but merely adhesive. One family of the first sub-order has one or two tentacles only, and another (the Acineta) has many tentacles, and some of the genera have the body without, and others with a lorica or a more or less covering sheath. *Acineta tuberosa* has the tentacles in bundles, which protrude through the transparent lorica, and the endoplasm can be seen within. It is a salt water form, and measures from $\frac{1}{500}$ th to $\frac{1}{300}$ th of an inch in length (Fig. 5).

These animalcules remain with their tentacles extended, and other freely-swimming minute Infusoria are stopped by the suckers at their tips. The endoplasm of the victim passes into the hollow of the tentacle and mixes with the soft tissue of the body of the Acineta. A third family includes the genus Dendrocometes, which settles on *Gammarus pulex*, and has rather flexible tentacles slightly branched at their extremities. Its embryos, which escape from the parent, are ciliated underneath only. The next family includes branching Acinetans, with many tentacles, a

host of individuals apparently arising from a common stem. But the tops of the ramified stem are really not separate individuals, and the whole mass must be looked upon as one (Fig. 6).

Some embryos with tentacles are produced from the ends of stems (Fig. 6, *b*), and those which are ciliated are derived from the thicker parts of the stem (Fig. 6, *a*).

The endoplast is ribbon-like, and is much contorted in the stolon and band parts of the main stem, and is continued as a band into the branchlets.

The next sub-order (the Actinaria) have the tentacles simple or ray-like, as in the family Ephalotidae, or represented by one or more retractile organs, which resemble a proboscis with or without cirri.

The genus Ophryodendron (Fig. 15) is the type of the last, and the species are very extraordinary-looking things. The animalcules may be solitary or in a little group, and then one has a long proboscis, flask-shaped, with a delicate tubular ending. The prey is caught on the proboscis, and gradually withdrawn into the body. They inhabit salt water, or fix on to the polyparies of Hydrozoa, or on to Crustacea. The embryos are ciliated.

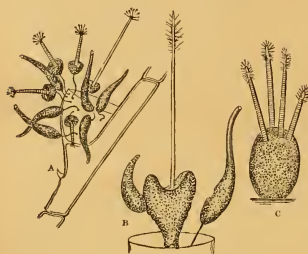


Fig. 15.—A, OPHRYODENDRON PEDICELLATUM ON A PLUMULARIA STEM (THE ELONGATE FORMS ARE THE VERMIFORM BODIES); B, MORE HIGHLY MAGNIFIED; C, O. MULTICELLATUM. (After Saville Kent.)

and the others are more or less vermiform or flask-shaped, with a delicate tubular ending. The prey is caught on the proboscis, and gradually withdrawn into the body. They inhabit salt water, or fix on to the polyparies of Hydrozoa, or on to Crustacea. The embryos are ciliated.

ORDER CILIATA.

In this order the animalcules are more or less covered with vibratile cilia, some of which may be modified into setae, styles, and hooks or uncini. A well-developed oral and anal aperture is mostly present.

The example (*Paramecium aurelia*) already given of this order brings these important characters before the mind. The order is divided into four sub-orders, of which the first is the Holotricha, or the Animalcules, which are closely covered all over with cilia, and usually furnished with trichocysts. Paramecium is the example of the first family of the sub-order (Fig. 2).

The Prorodontidae are the second family, and they are ovate or cylindrical, and the oral aperture is at one end or at the side. The canal (pharynx) leading from the mouth to the endoplasm is bounded by rod-like teeth, which are well seen in the genus Prorodon (Fig. 10).

The species *Enchelys farcimen*, which is found in stagnant water, and is from $\frac{1}{450}$ th to $\frac{1}{1000}$ th of an inch in length, has the oral cilia larger than the others, and the cuticle of the bag-shaped body and changeable-shaped body is soft (Fig. 16).

The flask-shaped, long-necked forms, with cilia over the whole body, and the mouth at the end, constitute the family Tracheloceridae. *Trachelocerca olor* has a body $\frac{1}{140}$ th of an inch in length, and lives in pond water. Its long neck and body obliquely striated with cilia, the several contractile vesicles, and its double endoplast, are all characteristic (Fig. 17).

The family Ichthyophthiriidae has the oral orifice in the midst of an adhesive disc, and the cilia of the oral region are setose and radiate internally. The species of the only genus is parasitic on trout and salmon and the loach. The contractile vesicles in the sub-globose or ovate body are numerous, and its endoplast is curved. Length, $\frac{1}{150}$ th of an inch (Fig. 14).

The family Colepidae contains ovate-shaped animalcules which have an indurated cuticle, and the oral aperture terminal. *Coleps hirtus* is a good example, and it will be noticed that the surface is furrowed, so as to present the appearance of being divided into numerous equal quadrangular spaces. These are indurated, and the intervening furrows are soft and ciliated.

The mouth is at one end, and the cilia near it are larger than the others, and the anus is at the opposite end. These Colepidae divide transversely, and *Coleps hirtus*, which is from $\frac{1}{400}$ th to $\frac{1}{500}$ th of an inch long, has three spinous processes at its nether end. It is a common species, living in pond water amongst confervæ. It is a voracious animalcule, and it may be seen in numbers in the neighbourhood of any dead animal or vegetable matters. These it takes in with its cilia, which form currents mouthwards, and it may distend its body considerably (Fig. 13).

During the process of natural fission, the extremities retain their usual aspect, but the newly-developed central area, where separation is to occur, is smooth, and thus, after division, one part of each *Coleps* is smooth, and the other like that of the parent.

There is a group of four families of these Holotricha which is characterised by the presence of a portion of the cuticle or ectoplasm formed into a flap, which may or may not vibrate. The Ophryoglenidae have the oral aperture situated at the bottom of a distinct depression in the body,

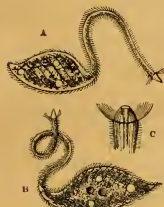


Fig. 17.—A, B, TRACHELO-
CERCA OLOR.
C, cilia of the mouth.

within which is a vibratile flap or membrane. The genus Ophryoglena has the family character, and the genus Trichoda resembles an Enchelys in shape, but the mouth is led to by an ovate furrow, and from its inner wall starts a vibratile flap. This genus is common in putrid infusions with the Enchelys already mentioned. A second family (the Pleuronemidae) has the membrane extending in front of the oral furrow in a hood-like manner, and it is not vibratile. The third family (the Lembidae) has long, vigorously-swimming, worm-shaped animalcules, and the membrane forms a long crest-like border to that furrowed part of the under surface of the body which extends from the front, backwards, to the oral aperture. It has large cilia along its inner border. *Lembus velifer* has a long spike-shaped body, narrow in front, thicker behind, where the contractile vesicle is seen, and the body is covered with long cilia. Beneath, in front, is the large membraniform expansion like a fin, broadest in front. The front part of the body is elastic, and can change its shape, and the hinder part is rounded. They increase by cross and longitudinal division (Fig. 9).

The last family of the group has been discovered by Leidy, and its species are most extraordinary-looking things, and lead very remarkable lives. They are freely moving, but rarely swimming animalcules, their movements being chiefly of a twisting and writhing kind. The shape is more or less elongate and spindle-shaped, and the cuticle is entirely ciliate. Sometimes there are undulating membranes on it. They occur as parasites within the intestine of the American White Ant (*Termites flavipes*). Leidy found some white ants which had their intestines, as seen through their translucent abdomen, considerably distended with a brown substance, which consisted mainly of these parasites,



Fig. 16.—EN-
CHELYS FAR-
CIMEN.

cv, Contractile vesicle; n, nucleus or endoplast.

decayed wood, and the filaments of one of the Algae. *Trichonomorpha agilis* (Fig. 18) has the cilia various in length, forming three or four distinct sets, and one of them is very long. The body is more or less separable into a smaller ovate head-like portion and a larger and inflated body. The oral aperture is indistinct, and is a rounded pore at the summit of the head, whence there passes backwards a tube to the endoplasm of the posterior part. There is a granular nucleus in the centre, but no contractile vesicle has been observed. The movements consist of an incessant retraction or shortening and bending to and fro of the head-like anterior region, accompanied by the rapid waving and swelling outwards of the long cilia. It is very possible that these animals may belong to another class of animals altogether.



FIG. 18.—*TRICHOMORPHA AGILIS*. (Leidy.)

The last group of the Holotrichous Ciliata contains one family, the Opalinidae, whose species are parasitic within the intestines of Amphibia and Invertebrata. The genus *Opalina* is very characteristic, and its species are mouthless, free-swimming, and they may be ovate or elongate in shape. The cilia cover the cuticle throughout, and this is striated. There are no extraordinary organs of prehension, and the spherical or oval endoplast is single in young individuals. It breaks up by repeated divisions, as growth proceeds, into innumerable minute rounded bodies, each having a clear peripheral zone and endoplastule. There is no contractile vesicle. *Opalina ranarum*, $\frac{1}{10}$ th to $\frac{1}{5}$ th of an inch long, is found in the intestines and rectum of the common frog and toad. Its body is usually ovate, flattened, evenly rounded posteriorly, and the anterior part is bluntly pointed. The minute embryos contained in cysts (Fig. 19, c) are found in the rectum and excreta of frogs in the early part of the year. They get into the water where tadpoles are developing, and are eaten by them. The cyst has its wall broken or dissolved in the digestive canal of the tadpole, and the embryo is set free. At this stage the young *Opalina* is long, egg-shaped, covered with cilia, and has a large endoplast and a number of corpuscles in the endoplasm (Fig. 19, n). After a short interval, the body becomes longer, slightly curved in front, and the endoplast becomes divided into two or four equal spheroidal portions (Fig. 19, i). After a while the pointed end becomes rounded, and the normal shape is attained (Fig. 19, a). When fully grown the animalcule begins to increase in numbers by fission, and the first division takes place obliquely (Fig. 19, b), so that one individual has a pointed posterior end, and the other a rounded-off one. The separated moieties subdivide over and over again, first obliquely and then transversely (Fig. 19, c, d), until at last the pieces are not more than $\frac{1}{100}$ th to $\frac{1}{200}$ th of an inch in length. These are long, oval in shape (Fig. 19, f), and soon become languid in their movements, and contract to a spherical shape, diminishing in bulk and becoming encysted. The endoplasts included in the animal at the encystment unite in one, after the swallowing by the tadpole, and this one is carried out with the young free-swimmer.

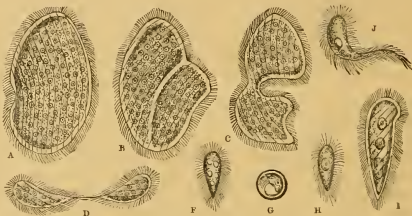


FIG. 19.—*OPALINA RANARUM*. (After Zeller and Englemann.)

A. Adult. B. Oblique division. C. Transverse fission. D. Fission. E. Last stage before encystment. G, H, I, J. Stages of growth of young.



FIG. 20.—*ANOPLOPHRYA PROLIFERA*.
(After Claparède and Lachmann.)

The endoplast is in the axis, is long and sub-cylindrical, and the contractile vesicles are numerous,

Another genus of the Opalinidae is *Anoplophrya*, and its species are parasitic within the intestinal organs of many Invertebrata. The type is *Anoplophrya prolifera* (Fig. 20), which is found in the intestinal cavities of various marine Annelids on the Norwegian coast. It is mouthless, long, widest in front, striated longitudinally, and ciliated along the striae.

and in two long rows. These animalcules increase by several divisions across the body, and their length is $\frac{1}{20}$ th of an inch.

SUB-ORDER HETEROTRICHA.

These Ciliata are free swimming or attached, naked or loricate, and the cilia form two widely distinct systems; those of the general surface being short, and those of the oral region large and like cirri. These oral cilia are either linear in their arrangement, or form more or less spiral or circular series. The cortical layers are well developed, and sometimes contain parallel muscular fibrillae.

The largest Infusoria are amongst this sub-order, which may be divided into a family, the Bursariadæ (Fig. 21), which has the cilia near the mouth confined to the left border of the mouth groove, and into six other families which have the mouth cilia in a spiral or circular series round the aperture. The first family of this second group has free-swimming animalcules, and the fringe of cilia around the oral aperture is confined to the ventral surface, and the anal orifice is behind and at the end. *Spirostomum ambiguum* is the type of the family, and is one of the largest animalcules, measuring $\frac{1}{10}$ th to $\frac{1}{8}$ th of an inch in length, and being visible to the naked eye, "gleaming," Saville Kent remarks, "like golden threads in the sunlight" (Fig. 22).

When they are placed in clean water off the duckweed on which they like to move, the body is long and filiform, has a tendency to twist itself and untwist, and the eye is struck by the long contractile vesicle which occupies much of the hinder part of the body, and by the endoplast, which is long and moniliform. The slit for the mouth is surrounded by cilia.



Fig. 22.—SPIROSTOMUM AMBIGUUM. (After Stein.)
cv, contractile vesicle.

the anterior border of the body is rounded off, and flat in front, and the mouth excavation occupying much of the ventral surface. There is an undulating membrane extending over the whole length of the right side of the peristome border. The contractile vesicle is canal-like, and breaks up into minor spaces (Fig. 12).

A most important family has the trumpet-shaped animalcules in it, which are usually found adherent by their narrow bases, and often freely swimming. The broad trumpet opening of these Stentoridæ is the region around the mouth, and the left-hand extremity is turned in spirally, forming a funnel-shaped groove which leads to the mouth. The right-hand limb is usually raised higher than the opposite one, and all the cilia around the mouth are large and strong. The cilia of the rest of the surface are small, and arranged in regular longitudinal rows, and there are occasional setæ. The endoplast is canal-like, and the contractile vesicle is an anterior circular dilatation, which gives off an annular branch that underlies the circumference of the peristome.

Stentor polymorphus (Fig. 23) is a large form, and the colour is produced by the presence of rich green chlorophyll granules. Its endoplast is moniliform, and the whole trumpet is $\frac{1}{25}$ th of an inch long. It lives in groups, and the stems of all are immersed in a mucus which they secrete and hold on by. When swimming the shape is altered, and may be pear-shaped or top-shaped, and they fix them-

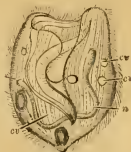


Fig. 21.—BURSARIA TRUNCATELLA. (After Stein.)
cv, contractile vesicle; en, endoplast curved.

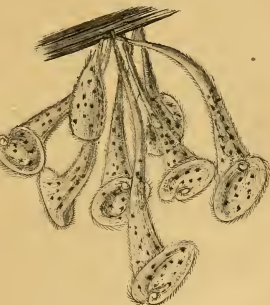


Fig. 23.—STENTOR POLYMORPHUS.

selves at pleasure. They increase in numbers by oblique fission, and a rudimentary mouth fringe appears, and only in the part of the body which will require it after division. They live in standing water among living and dead vegetation. One of the genus has blue colouring matter, and another, in addition to its green chlorophyll, has spots of a brilliant scarlet, and a third is black. The species of the genus *Folliculina* secretes a lorica, and the peristome opening occupies the end of the projecting part of the animalcule (Fig. 24). *Tintinnus lagenula* is a type of a family of this sub-order (Fig. 7).

SUB-ORDER PERITRICHA.

These Ciliata have the body smooth, except where there is a circular or spiral wreath of cilia in front. Sometimes there is a second encircling wreath which may be at the posterior part of the body, or at the middle. When the anterior circle of cilia assumes a spiral form the right limb of the part around the mouth is mostly band-like and long. These animalcules may be free swimming or attached in colonies, and in this case often forming branching growths. They multiply by transverse and longitudinal fission, and by conjugation.

This very important sub-order is well divided into those families which are free swimming, and those which are sedentary or attached.

There are seven families of free swimmers, and in the first, containing the genus *Torquatella*, the cilia around the mouth are replaced by a vibratile collar. The second family has the animalcules protected by a silicious covering or lorica, and the third has no lorica, and there are retractile tentacles with the fringe of cilia in the front.



Fig. 24.—FOLLICULINA AMPULLA.
(Modified after Stein.)

A, Protruding form, and B, contracted in lorica; C, Spirorhis shell with animalcules attached.

Halteria grandinella (Fig. 25) is the type of the fourth family, and is a free-swimming globular animalcule, and it has the oral aperture at one end, and associated with a spiral or sub-circular wreath of large ciliate cilia. There is a zone of long hair-like setæ around the body equatorially, and they enable the creature to jump in a most extraordinary manner. They roll themselves about, and suddenly leap backwards on to one side. There is a contractile vesicle and a spherical endoplast. The length is from $\frac{1}{800}$ th to $\frac{1}{3500}$ th of an inch, and it inhabits pond water.

Another family has the animalcules pear-shaped; the mouth is lateral, and there is a fringe of cilia around the body equatorially. *Urocentrum turbo* (Fig. 26) is the example, and the zones of cilia are in front, and equatorially, there being a terminal style, which is flexible, and enables the animalcule to adhere. The endoplast and contractile vesicle are very visible. It rotates like a top in the water, and moves forwards and backwards, and fixes itself, and spins backwards and forwards, so as to twist and untwist its stalk. The contractile vesicle has two or four sinuses, and the contraction expels the water visibly externally. They increase by transverse division.

In the family Urceolaridæ the wreath of cilia is near the adhesive disc-like posterior end, and the seventh family is peculiarised by its terminal setæ, and a spiral adoral wreath of cilia.

The family which contains the genus *Dictyocysta* is characterised by the possession of a beautiful helmet-shaped or bell-shaped silicious lorica, which is usually perforated so as to resemble a fine lace-work. The species are from salt waters, are free swimmers in the Mediterranean and south-west coast of England. In their tests they closely resemble Polycistinae.

The family Vorticellidæ comprehends the Peritricha which are fixed during the greater part of their lives, and which are only temporarily free swimming. These are the "Bell Animalcules"

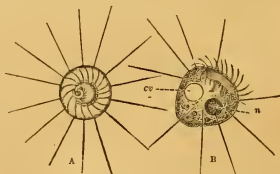


Fig. 25.—HALTERIA GRANDINELLA.
A, Ventral, B, lateral, aspect; cv, contractile vesicle; n, nucleus.

which form colonies, and the commonest of which have their stalks contracting, often in a corkscrew shape, the end of the bell being provided with a circle of long active cilia. Occasionally they may be seen freely swimming, and then there is a second circle of cilia at the tail end; but they soon settle down, become attached, and grow a stalk, the lower circle of cilia disappearing. Very often the group of these stalked Vorticellidae are so large that they are visible to the naked eye, and hence they were amongst the first animalcules described. There are numerous genera, arranged in sub-families, and some have no stalk and others have it, and they may be solitary or social, arranged in branching groups on a common stem or immersed in mucus. The animalcules are highly contractile, and vary in shape from that of a long egg to sub-cylindrical, or a long or broad bell shape (Fig. 11). The free end of the bell consists of an outer raised border, sometimes but not always ciliated, and this closes the opening like a sphincter when the animalcule shuts up. As it reopens this peristome is seen to environ a spiral membrane with a circle of cilia on its free surface, and this projects beyond the peristome and the cilia produce very forcible currents in the water. On one side the circle is incomplete, and leads to a furrow which is often prolonged backwards on the body to a canal-like opening to the mouth. The movements of the cilia cause the particles of food to take the direction of this furrow, which has often a long solitary cilium at its free end. The spiral part, or disc, can be protruded or retracted. The endoplast is band-like and large, and the contractile vesicle is single, spherical, and is placed close to the anal aperture, which is distinct near the furrow. The stalk, when it exists in its highest degree of perfection, has an outer cuticle continuous with that of the body, and an inner spiral tissue more or less longitudinally fibrous, which is continuous with the myophan layer of the hinder part of the bell. Contraction produces spiral winding of the stem in some species, and a slow unwinding happens subsequently.

The animalcules rarely divide by transverse and usually by longitudinal fission, which takes place through the endoplast and contractile vesicle. The offshoot grows a circle of cilia close to the stalk, which does not divide, and after a while it escapes as a free swimmer. In some species there is a free-swimming and small animalcule, which finally settles on the side of one of the larger fixed individuals, and either penetration occurs or the contents of the smaller pass into the larger. The endoplast subsequently develops a host of germs, which escape and become like the parents with growth.

In the sub-family Vorticellina the animalcules are naked, long, without a stem, and are sessile on substances; some have a distinct sucker, by which they cling on, mostly to moving invertebrata and sometimes to weeds in fresh water. One of the genera (*Spirochona*) has solitary individuals, and the peristome is developed into a spiral funnel, and in *Stylochona* there is a rigid pedicle or stem instead of a sucker at the tail end. Then there is a genus with all the characters of the genus *Vorticella*, but the stem is rigid and uncontractile, and the animals are solitary; and in the genus *Pyxidium* the solitary animalcules have a rigid stem and a ciliary disc projecting beyond the peristome. These forms lead up to *Vorticella* as a genus, which is the type

of the family. *Vorticella nebulifera* (Fig. 27) is common in ponds attached to duckweed or other water plants, and is a very beautiful object under the microscope. The bell-shaped body of each individual is about $\frac{1}{10}$ th of an inch in length, and is attached to a long



Fig. 26.—A, B, UROCENTRUM TURBO; C, TRANSVERSE FISSION.



Fig. 27.—VORTICELLA NEBULIFERA.
cu, Contractile vesicle.

flexible stem, which is for a while extended to the utmost, the cilia of the disc and peristome being in full action. Suddenly the stem contracts, becomes spiral, and the body closes slightly and bends on its stalk. Then the oral end opens, the cilia move again, and the stalk is drawn out to the utmost. This goes on very irregularly in a colony of a score or more of individuals, so that whilst some are contracted others are in full play. The currents in the water, produced by the ciliary fringes, are considerable and move much disintegrated matter into the oral grooves. The phenomena of fission and conjugation may be seen in the same colony at the same time, and every now and then a bud moves off by means of its hinder circle of cilia.

In the genus *Carchesium*, which belongs to this group, a host of animalcules are on branchlets springing from a common stem. Usually the bell-shaped bodies are on one side of their branchlet, and each one has a stem continuous with the branch and main stem. A muscular tissue resembling that of *Vorticella* is in the stem and its prolongations, but it is discontinuous, so that each body can contract without the others, and each branchlet can do the same irrespectively of others, and the whole may contract with the primary stem and form a small globular mulberry-looking mass.

The species live in fresh and sometimes in salt water, and the whole colony originates in the fission of one individual and its stalk, and is fully developed by the successive longitudinal fissions of body after body (Fig. 28, D).

The genus *Zoothamnium* has the animalcules like those of *Vorticella*, but often dissimilar in shape and of two sizes, and they are placed at the end of a branching, highly contractile stem. The

Fig. 28.—A, *ZOOETHAMNIUM NIVEUM* (Saville Kent); B, SINGLE ANIMALCULE, MORE HIGHLY MAGNIFIED; C, *EPISTYLIS UMBILICATA*; D, BRANCHLET OF *CARCHESIUM POLYPINUM*; E, AN *EPISTYLIS* GROWING ON A CYCLOPS.

internal muscle of the stem is continuous throughout. This is not spiral in its construction. In *Zoothamnium niveum*, which is a salt-water form, there are spherical animalcules of large size near the bases of the primary branches, and the smaller ones at the ends of branchlets are long bell-shaped (Fig. 28, A, B).

Another genus, *Epistylis*, with its animalcules closely resembling *Vorticella*, has them attached in numbers to a rigid, uncontractile, branching, tree-like stem, and the bodies are of the same size throughout. *Epistylis flavicans* forms slimy encrustations on water plants and on the sides of aquaria. Many species settle on small crustacea (Fig. 28, C, E).

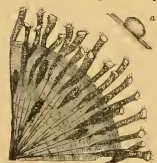


Fig. 30.—*OPHRYDIUM ECHINORNIS*. (After Saville Kent)
a, O. sessile, natural size.

The last sub-family, the Ophrydinae, contains *Vorticella*-like animalcules which excrete and inhabit a soft mucilaginous sheath or mass which may contain many.



Fig. 29.—*PYXICOLA PYXIDIFORMIS*.

Ophrydium eichhornii (Fig. 30) is an example, and it forms attached gelatinous masses in which are numerous individuals, each with its slender pedicle. The body is long and narrow, and the whole is very elastic. They live in fresh water, attached to Anacharis, and about a hundred may be in a mass measuring $\frac{1}{80}$ th of an inch. They increase by transverse as well as by longitudinal fission.

SUB-ORDER HYPOTRICHA.

These animalcules are free swimming, and the locomotive cilia are confined to the inferior or ventral surface, and are often modified into setæ and hooks. The superior surface is either smooth, or has some immobile setæ on it. The mouth and anus are ventral. Saville Kent subdivides this group into six families and forty-two genera. *Chlamydodon mnemosyne* is the type of one family, and it has a short, kidney-shaped body, the front being wide and the dorsal surface convex, and the ventral having a striated border. The cilia are the most conspicuous anteriorly and they project as a fringe. The oral aperture has a bundle of rods in its membrane. The endoplast is single and ovate, and there are many contractile vesicles. It inhabits salt water (Fig. 31).



Fig. 31.—CHLAMYDODON MNEMOSYNE. A, Under, B, side view.

Another family, the Dysteriidae, mostly inhabit salt water, and these free swimmers are mostly provided with a lorica either single or made up of two joined or detached valves like a small crustacean. The cilia are on the lower surface and the oral aperture leads to a canal, or pharynx, with a horny tube, or rods. The animalcules have a conspicuous tail-like style, or a group of setæ.



Fig. 32.—DYSTERIA ARMATA. (After Huxley.) A, Left side; B, C, pharyngeal apparatus.

Dysteria armata, a salt-water form, $\frac{1}{16}$ th to $\frac{1}{80}$ th of an inch in length, is remarkable for the anatomy of the pharynx. The oral fossa has a curved rod which terminates in fork-like teeth, and which is lost in the walls of the fossa. Then comes the armature of the pharynx, which consists of two portions—an anterior rounded mass in opposition with a much elongated styliform posterior portion. These animalcules live in swarms among the confervoid Algae which coat the shells of limpets and periwinkles (Fig. 32).

The family Peritromidae has the ventral surface finely ciliate, and there is a curve of powerful cirri around or near the mouth, and the pharynx is unarmed.

A host of flexible or persistent in shape animalcules, with front, ventral, and rear styles, and hooks and setæ at the margin, belong to the Oxytrichidae. The common *Stylonychia mytilus* is an admirable example. It has a hard covering, or lorica, and the neighbourhood of the mouth has a great curve of long cilia on an undulating membrane. There are usually eight styles in front, five claw-like hooks on the ventral surface, and five straight anal styles. The marginal setæ form a border, and there are three long tail-like setæ. There are two endoplasts, sometimes divided, and a contractile vesicle. It inhabits fresh water, and the largest are $\frac{1}{2}$ nd of an inch long (Fig. 8).

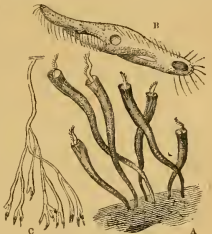


Fig. 33.—STYCHOTRICHA REMEX. (After Hudson.)

A, Animals in tubes; B, free animalcule; C, diagram of Schizosiphon.

Another species (*Stichotricha remex*, Fig. 33) has the cilia of the apex of the peristomial border very long, and the body is lanceolate, and inhabits a slender, brown tube, three or four times as long as the body, which projects from it with a twist.



Fig. 34.—EUPLOTES CHARON.

Closely allied to these dwellers in separate tubes is a species (*Schizosiphon socialis*) which forms colonies that build up a branching tube. Another of this great family is *Uroleptus piscis*, and it is remarkable for its attenuated end, two endoplasts, and great curved ciliated peristome.

A family of the Hypotricha has no setæ along the margin, or they are rudimentary, but there is a lorica, and there are ventral and anal styles, or else hooks. In *Euplotes*

charon the dorsal surface of the body is ribbed, as it were, and there are seven frontal and three ventral styles, besides five posterior strong setæ (Fig. 34).

ORDER CILIO-FLAGELLATA.

The animalcules of this order are readily distinguished by their bodies being more or less ciliated, and by their having a long lash-like flagellum. The mouth is usually distinct. Saville Kent divides them into four families and sixteen genera, and the individuals are occasionally very numerous, producing the phosphorescent condition of the sea, and discolouring fresh and salt water. Most of the Cilio-flagellata, a type of which has already been noticed (pp. 356-7), are small, $\frac{1}{500}$ th of an inch being the greatest length, but amongst the genus *Ceratium* there are some large forms, some reaching $\frac{1}{72}$ th of an inch in length. They are found in fresh and in salt water; and, so far as is known, none are parasitic or sedentary; but during one of the reproductive phases encystment occurs, and a period of quiescence precedes the escape of the young. They are active swimmers as a rule, the lash-like flagellum (in rare instances there are two) enabling rapid and irregular motion easy, and the cilia produce ordinary movement. Fission occurs, but the reproductive phenomena have not been observed satisfactorily. Some of the Cilio-flagellata are naked, and others have a shell, or horny cuirass, which may be smooth or ornamented, and often prolonged into horn-like processes. Some of these lorice have been preserved in the strata of the Chalk, and are referred to the genus *Ceratium*. The general character of the group having been given already, it is only necessary to observe that the family Peridinidae contains ten genera. In all there is a distinct ciliary girdle, and one flagellum. In a doubtful genus there are two of these organs. In some of the genera the ciliary girdle is central, in others excentric, and in one it is terminal. Some genera have a cuirass, and many others are naked. *Melodinium*, already noticed (p. 357), is an example of a naked, and *Ceratium* of a cuirassed and horned genus. *Peridinium* has no horn-like processes, and the cuirass is faceted (Fig. 4, A-H).

The second family* has one vibratile flagellum, and one which is trailed, and the body changes in shape, like *Amœba*; and the third family† has the body clothed with long setose cilia, and a terminal flagellum, the body shape being persistent. A fourth family has a wreath-like crest or collar of cilia, and in the midst a flagellum, which may or may not be retractile;‡ and the last family,§ which links the order with that of the Ciliata, has a more or less perfect ciliary covering, and a flagellum. The colours differ, and there may or may not be a red spot in these families. Yellow, light-brown, green, pink, reddish-brown, vermilion, are common colours; and usually the endoplasm is transparent, and holds coloured matters in suspension. *Peridinium splendormaris* of Naples is highly phosphorescent, and *P. sanguineum*, of salt-water pools and the sea-shore of India, is green when young, and with growth a number of oil globules is secreted within, and the green colour disappears, and a bright red tint comes on, just before encystment. The red colour of patches of the sea is due to this form, in many instances, and it is noteworthy that the presence of these animalcules renders water very disagreeable.



Fig. 35.—*MONAS DALLINGERI*. (Saville Kent.)

A, a, Adult; c, about to encyst; d, e, f, encystment—formation of spores which are liberated as monads; g, h, conjugation; i, encystment from conjugation; j, bursting of and liberation of spores (small).

ORDER FLAGELLATA.

These animalcules, generally very minute, have one or more long slender flagella; there are in some instances pseudopodia. The mouth may be doubtfully present, and food may be taken in at one spot, or anywhere.

One or more contractile vesicles are almost invariably present. They increase by fission, or by breaking up of the endoplasm in the encysted state.

This definition explains how difficult it is to limit the lower Flagellata. It is possible that many of the so-called Flagellata are stages of plants, and indeed it seems impossible to draw a hard and

* *Heteromastigidae* (Fig. 4, K).

† *Mallomonadidae* (Fig. 4, L).

‡ *Stephanomonadidae* (Fig. 4, I).

§ *Trichonemidae* (Fig. 4, J).

fast line where the animal and vegetable kingdoms branch off. Saville Kent has paid much attention to the order, and his descriptions and classification are excellent.

The Flagellata may be divided into three sub-orders: in the first there is no defined mouth, and the food may be taken in by any part of the body, and in the second the food is received in the

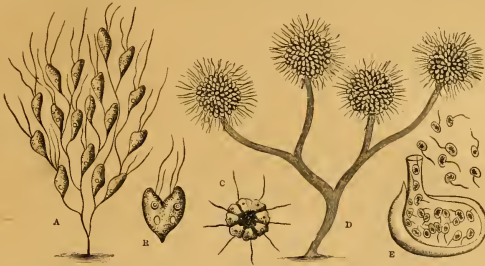


Fig. 36.—A, CLADONEMA LAXA. (After Saville Kent.) B, ANIMALCULE DIVIDING; C, ANTHOPHYSA VEGETANS, SWIMMING CLUSTER; D, ANTHOPHYSA VEGETANS, SHORT BRANCHING COLONY; E, SPOROXYST LIBERATING GERMS.

anterior region. A true opening for food exists in the third, which have a non-ciliated body with a flagellum. The sections of the first sub-order are the Trypanosomata, membranous organisms found in the blood of frogs and toads; the Rhizoflagellata, which have amœbiform bodies and a flagellum; the Radio-flagellata, with or without a lorica, having a flagellum, and ray-like pseudopodia; and the Flagellata-Pantostomata proper, which have a flagellum and the food incepted anywhere. A host of genera belong to this sub-order and Monas may be represented by

Monas dallingeri, $\frac{1}{4000}$ th of an inch in length. It has one flagellum, which is flexible when young, and rigid towards the base in old specimens (Fig. 35).

Cercomonas has a caudal filament besides a flagellum (*Cercomonas typica*, Fig. 3).

The genus *Cladonema*, as the name implies, has a branching form, and the ovate bodies are attached to thread-like pedicles. There are two flagella (Fig. 36, A, B).

Anthophysa, a genus belonging to the same family, has small individuals $\frac{1}{3500}$ th to $\frac{1}{4000}$ th of an inch in length, and is in the form of clusters of fifty or sixty bodies at the ends of branching horny pedicles. These have contractile vesicles (Fig. 36, C, D).

Rhipidodendron splendidum (Fig. 37) is in masses, $\frac{1}{7}$ th of an inch long, and has its bodies with two flagella. These are in a branching mass, like a fan in shape.

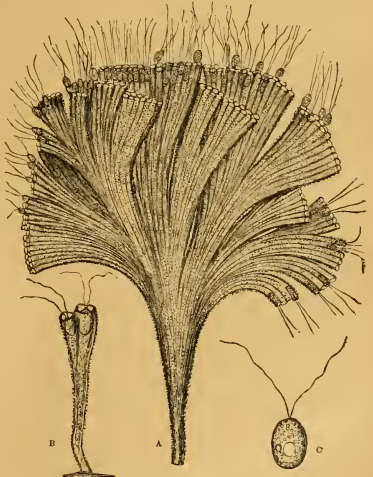


Fig. 37.—RHIPIDODENDRON SPLENDIDUM.
A, Colony; B, animalcule bifurcating; C, isolated monad.

The second sub-order comprehends Saville Kent's division of the collared monads (*Choano-flagellata*), with individuals varying from $\frac{1}{1000}$ th to $\frac{1}{3000}$ th of an inch in length, and some of which resemble the collared cells of sponges. It consists of three families. In the first the animalcules are naked, and either attached or free; the genera *Monosiga*, *Codosiga*, and *Astrosiga* are examples (Plate 72, Figs. 1—8). The forms of the second have a lorica, which may be solitary, as in *Salpingæca* and *Lagenæca*, and united in *Polynæca* (Plate 72, Figs. 9—18).

In the sub-order of the *Flagellata*, with a definite region for inception of food (*Eustomata*), the most interesting examples are the genera *Noctiluca* and *Euglena*. The first is one of the greatest producers of the phosphorescence of the sea.

Noctiluca miliaris, from $\frac{1}{20}$ th to $\frac{1}{30}$ th of an inch in diameter, is peach-shaped, and has a distinct meridional groove to its hyaline body. The mouth fossa is at one end of the groove, and has on one side a



Fig. 38.—A, *NOCTILUCA MILIARIS*; B, SAME WITH BUDS (from Photograph after Brooks); C, IN SECTION. (After Huxley.)

n, nucleus; f, flagellum; t, tentacle; d, denticle; an, anus.

hard projecting ridge, close to one end of which arises the flagellum. Close by arises a tentacle about as long as the body, and there is a rod-like induration of the cuticle, extending in a straight line from the aboral extremity of the groove. The endoplast is oval. They exist in countless multitudes, and their greenish-silvery light is produced just underneath the cuticle in irregular flashes. They increase by transverse fission, accompanied by encystment and loss of the flagellum and tentacle. Under certain circumstances, the endoplast breaks up, and the protoplasmic contents of the cyst collect in one spot and form by division into many minute nodular masses. These cause the cuticle to rise, and finally they penetrate it and develop flagella. They become detached and swim as germs (Fig. 38).

Conjugation is also observed. The *Noctiluca* live on minute floating Algae, which may be seen amongst the vacuoles of the irregular endoplasm.

CLASSIFICATION.—CLASS INFUSORIA.

ORDER TENTACULIFERA	.	.	.	.	.	.	.	.	Sub-order	{ Suctorina.
										{ Actinaria.
										{ Holotricha.
" CILIATA	.	.	.	.	.	.	.	.	"	{ Heterotricha.
										{ Peritricha.
										{ Hypotricha.
" CHOANO-FLAGELLATA.										
" FLAGELLATA	.	.	.	.	.	.	.	.	"	{ Pantostomata.
										{ Choano-flagellata.
										{ Eustomata.

The writings of Claparède and Lachmann, Stein and Huxley, have been used by the author; but his greatest obligations are to Mr. Saville Kent, whose excellent Manual of the Infusoria has been quoted largely, and often word for word.

P MARTIN DUNCAN.



COLLARED MONADS (*Choano-flagellata*).

1, *Monosiga fusiformis*; 2, *Colosiga alloides*; 3, *C. grossularia*; 4, *C. umbellata*; 5, *C. cymosa*; 6, *C. botrytis*; 7, *Astrosiga juncta*; 8, *A. mouliiformis*; 9, *Salpingea marina*; 10, *S. ampulla*; 11, *S. steini*; 12, *S. napiformis*; 13, *S. elatris*; 14, *S. vaginicola*; 15, *S. cornutum*; 16, *S. tintinnabulum*; 17, *Lageunea cuspidata*; 18, *Polyarea dichotoma*—all highly magnified. (Modified after Saville Kent and Stein.)

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